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Are Promotion Programs Needed to Establish Off-Grid Solar Energy Markets? Evidence from Rural Burkina Faso

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 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 percent compared to eight percent for branded SHS. We compare potential quality differences as well as the cost-effectiveness of branded and non-branded solar. We show that non-branded SHSs provide 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 might not be needed to establish sustainable off-grid solar markets. The challenge however is to reach the very poor who are unable to bring up investment costs for any electricity.

JEL Classification: D12, D40, O13, O33, Q41

Keywords: Energy access; energy poverty; technology adoption; branded products; cost-effectiveness; rural Africa

October 2016

1 Gunther Bensch, Max Huppertz, Jörg Langbein, All RWI; Michael Grimm, University of Passau, Erasmus University of Rotterdam, IZA; Jörg Peters, RWI, University of the Witwatersrand, Johannesburg - *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.* *– All correspondence to: Jörg Peters, RWI, Hohenzollernstr. 1/3, 45128 Essen, Germany, e-mail: peters@rwi-essen.de*

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. For sub-Saharan Africa, this would imply full electricity coverage 50 years earlier than on current trends (Africa Progress Panel, 2015). Achieving this by extending national electricity grids to unserved rural areas would require enormous investments (Lighting Global, 2016).

Off-grid solar technologies such as solar home systems (SHSs) and smaller 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 little evidence that exists suggests that off-grid solar has significant livelihood impacts to households (see Bensch et al., 2013*a*, Grimm et al., 2016, Samad et al., 2013, and Arráiz and Calero, 2015). 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 (Lighting Global, 2016).

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 (see Lighting Global, 2016). Specifically, we analyze whether market forces are sufficient to sustain the market for small-scale solar products without further 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 percent 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 percent 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

[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. (2013*b*).

extensively for improved cookstoves (see the systematic reviews by Rehfuess et al., 2014; Lewis and Pattanayak, 2012), including studies on Burkina Faso (Bensch et al., 2015; Ouedraogo, 2006; Sawadogo, 1989). For off-grid solar products, empirical evidence is sparse. Khandker et al. (2014) and Harish et al. (2013) study SHS adoption among households in India that opted for the systems mainly as a backup source due to the unreliability of grid electricity. Grimm et al. (2016) examine usage and impacts of pico-PV devices in Rwanda.

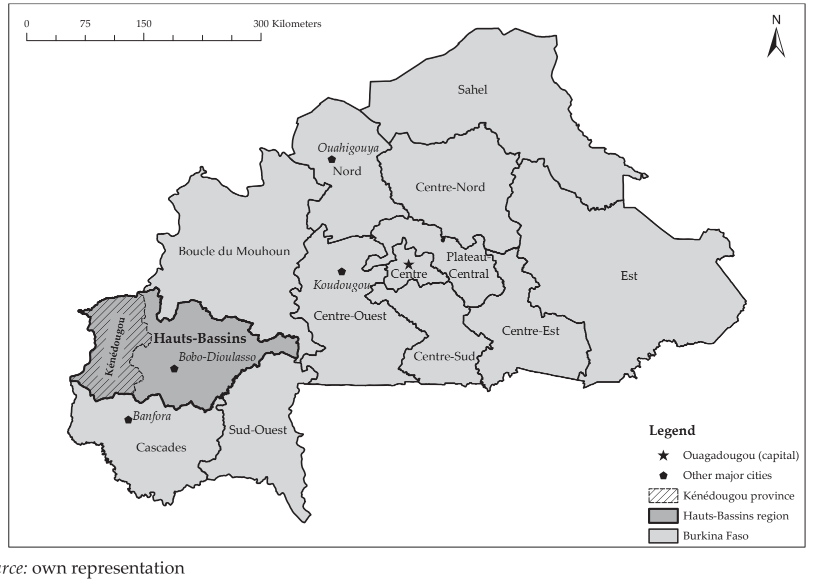
The rest of the paper proceeds as follows: Section 2 describes the broader electricity access context in Burkina Faso and in the study region more specifically. Section 3 describes SHS uptake over time, and explores the socio-economic characteristics of users of non-branded and branded SHSs, respectively. 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 (World Bank, 2013). The electrification rate is stalling at 14 percent nationally (40 percent in urban areas and a mere five percent in rural areas). Electricity consumption per capita was about 50 kilowatt-hours (kWh) in 2013 (World Bank, 2013), which is way lower than in other West-African countries such as Côte d’Ivoire (252 kWh) or Cameroon (278 kWh, OECD/ IEA, 2014).

The focal region of this study is Kénédougou province in the Hauts-Bassins region (see Figure 1). Roughly 92 percent of its 350,000 inhabitants live in rural areas (Institut National de la Statistique et de la Démographie, 2014). 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.

Figure 1: Map of Burkina Faso indicating the study area



Source: own representation

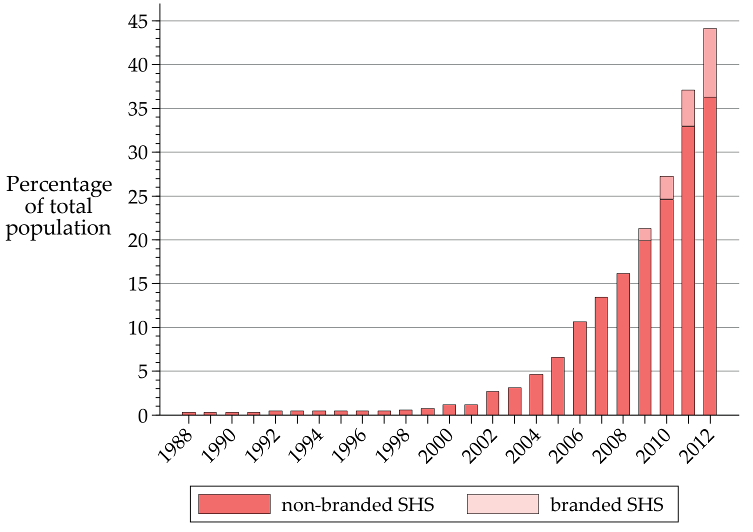
The company was set up by a Dutch non-profit foundation that received co-financing from the European Union and the Netherlands, among others, and already had over five years of commercial experience in rural electrification with solar home systems in Mali and South Africa. The company obtained the national 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 cost 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 percent of the 880 surveyed households possessed a non-branded SHS. In comparison, 7.9 percent of all households used branded SHSs from the service provider. This aggregate SHS penetration rate of 44 percent is a clear increase compared to the 28 percent in the first survey in 2010, when the service provider had reached a share of 3 percent (Bensch et al. 2013); it is also substantially higher than the official average estimate across sub-Saharan Africa of five percent and also higher than what we have found in other solar power access studies in sub-Saharan Africa (Africa Progress Panel, 2015; Grimm and Peters, 2016). Figure 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 one to six years. The average non-branded SHS in our sample has been operating for 3.9 years. This compares to about a year for branded SHSs.

Figure 2: Cumulative SHS take-up over time



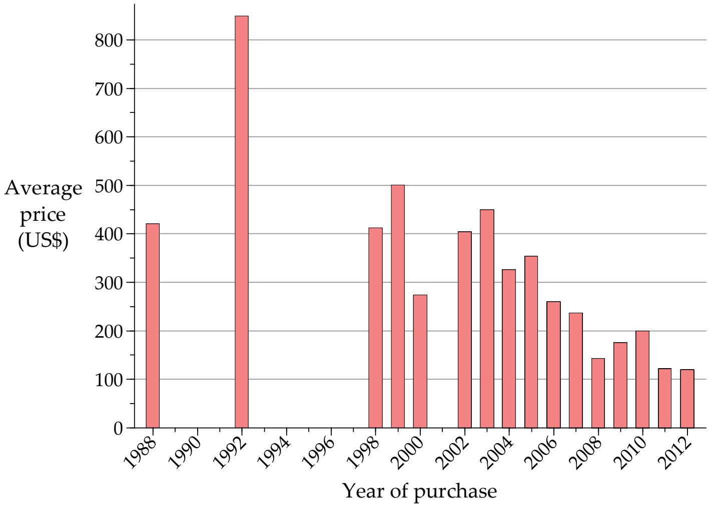
Notes: The graph is based on all 880 observations from our sample. Percentage values for all years relate to the 2012 sample composition.

Source: Burkina SHS dataset 2012.

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 Figure 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 percent.

Figure 3: Evolution of the average price of non-branded SHSs



Note: Based on purchase prices reported by the 229 owners of non-branded SHSs in our sample. Throughout the paper, we use World Bank data on Burkina Faso's consumer price index to correct for inflation and convert any non-2012 figures, first, to 2012 West African CFA Francs and then into 2012 US$. CPI data and exchange rates are available at http://data.worldbank.org/.

Source: Burkina SHS data set 2012.

Both figures only plot the purchase date and price of SHSs currently in operation. The lack of information on purchase prices and purchase dates for previously owned SHSs might have a distorting effect.[2] Yet, we know that merely five percent of owners of non-branded SHSs and 14 percent of customers of branded SHSs used another SHS before and that four percent abandoned SHS usage within the two years before the survey. This underpins the existence of a real price decrease and an increase in uptake underlying our data that clearly started before the entrance of the service provider.

[2] Seeing many purchases in recent years and fewer purchases longer ago could simply be due to the replacement of SHSs and would not necessarily imply an increase in the adoption of SHSs over time. In addition, the values for earlier years may be underestimated, since some households have not existed throughout the depicted period. This underestimation is, however, likely to be negligible as we know that more than 80 percent of households existed at least since the year 2000. Likewise, if cheaper SHSs tend to break down earlier, the prices of older SHSs still in operation will tend to be relatively high. These older SHSs would have been higher-quality products, and thus have been more expensive than the average new SHSs even if the price level had stayed constant.

3.2 Socio-economic characteristics of SHS users

In this section we examine which segments of the population adopted the SHS. Our main interest lies in the adoption of non-branded SHSs bought on local markets and the contribution of the SHS promotion program to fostering these markets, e.g. by attracting specific customers. For that purpose, we look at three types of SHS-adopting households: households adopting an SHS early when only non-branded SHS were available (i.e. before 2009), households that chose a branded SHS and those who chose a non-branded SHS in 2009 or later once the service provider was operational.

We estimate a multinomial logit model of a household's probability to adopt a certain type of SHS (columns (1) to (3) of Table 1). Non-adopters serve as the base category to be compared with. The right-hand-side variables cover several socio-demographic household characteristics as well as proxies for household wealth and income that are potentially important in the adoption of an SHS: They include, among others, the household head's education, an asset index[3], and whether the household is polygamous. Being polygamous can be seen as a proxy for wealth, as the number of spouses typically increases with income and wealth. We also include the distance to the closest service provider and district effects in the model. See Table A.1 in Appendix A for descriptive statistics on these right-hand-side variables.

While the multinomial logit estimations do not allow deriving causal insights, they enable us to identify significant correlates of purchasing an SHS.[4] We find the most significant correlate of SHS uptake of either type to be household wealth. Both non-

[3] The base inputs of the asset index are: a dummy that is equal to one if the household does not have a thatched roof (but something more sturdy), a dummy that is equal to one if the household does not have an earthen floor (but something more sturdy), a dummy that is equal to one if the household does not have clay walls (but something more sturdy); dummies for owning a bicycle, motorcycle or car; dummies for owning a phone or radio (i.e. appliances that are generally bought irrespective of electricity access); dummies for owning cows or sheep. We extract the first principal component-factor from these data to construct the index, which has a standard normal distribution.

[4] Note that the raw multinomial log-odds estimates themselves cannot be interpreted intuitively.

Table 1: Correlates of using a branded or non-branded SHS

Dependent variable:	Raw coefficient			Relative risk ratio
Estimation method:	multinomial logit			multinomial logit
	non-branded SHS (before 2009)	non-branded SHS (2009 or later)	branded SHS	branded SHS
Independent Variable	(1)	(2)	(3)	(4)
Household size (log)	-0.112	0.374	0.694**	1.378
	[0.71]	[0.22]	[0.01]	[0.37]
Polygamous household	-0.103	0.075	0.185	1.116
	[0.74]	[0.78]	[0.51]	[0.75]
Age of head of household	-0.044	-0.084	-0.125**	0.959
	[0.48]	[0.15]	[0.04]	[0.35]
Squared age of head of household	0.000	0.001	0.001*	1.000
	[0.82]	[0.27]	[0.06]	[0.23]
Head of household is a subsistence farmer	-1.014**	0.065	-0.280	0.708
	[0.03]	[0.91]	[0.56]	[0.57]
Head of household has a formal education	0.048	0.227	0.177	0.951
	[0.87]	[0.37]	[0.53]	[0.87]
Household receives remittances	-13.169***	0.454	-0.812	0.282
	[0.00]	[0.57]	[0.47]	[0.34]
Household has an account at a bank or savings institutions	0.353	0.018	-0.088	0.899
	[0.29]	[0.96]	[0.80]	[0.77]
Distance to next service agency	0.023***	-0.005	0.011	1.016
	[0.01]	[0.52]	[0.33]	[0.19]
Monthly household expenditures excluding energy (log)	0.327	0.319**	0.672***	1.423*
	[0.11]	[0.04]	[0.00]	[0.08]
Asset index	1.298***	0.789***	0.817***	1.029
	[0.00]	[0.00]	[0.00]	[0.89]
District dummies	Yes	Yes	Yes	Yes
Constant	-3.756	-3.574*	-6.216***	0.071
	[0.12]	[0.09]	[0.01]	[0.28]
Base case	non-adopters			non-branded SHS (2009 or later)
Weighted proportion in overall sample				
non-adopters	55.8 %			
early-adopting households of non-branded SHS	16.2 %			
households with non-branded SHS (2009 or later)	20.1 %			
households with branded SHS	7.9 %			

Note: Based on 839 observations, *p*-values in squared brackets. Stars indicate significance level with * p<0.1; ** p<0.05; *** p<0.01. Observations are weighted, since customers of the service provider have been oversampled as part of the sampling design.

energy expenditures and the asset index have statistically significant, positive coefficients. Not surprisingly, more affluent households are thus significantly more likely to choose an SHS than to remain without electricity. As one would expect, the most well-off seem to have been the early adopters represented in column (1) that are most likely to have non-agricultural incomes and least likely to be reliant on remittances. Interestingly, the coefficient for the variable *distance to next service agency* is as well statistically significant. This correlation suggests that service agencies have rather been setup in areas with less early-adopting SHS users. In fact, as noted before, most SHS service subscribers have been first-time users of SHS, with merely 14 percent of customers of branded SHSs already having owned another SHS before. At the same time, the share of adopters of branded products does not increase as households live closer to a service agency. Instead, users of branded SHS show significant socio-demographic differences in terms of age and household size as compared to non-adopters.

In order to test whether such differences also exist between users of branded SHSs and those of non-branded SHSs, i.e. to assess whether the donor-promoted program managed to addressed other household types, we derive relative risk ratios for the choice between the two types of SHSs (see column (4) of Table 1). The only significant difference (at the ten-percent level) for our variables of interest is related to non-energy expenditures. The relative probability of choosing a branded SHS over choosing a non-branded SHS is 4.2 percent higher for households that have a 10 percent higher expenditure level – given that the other variables in the model are held constant. Apparently, income plays a larger role in using a branded SHS than in purchasing a non-branded SHS. The reason for this is probably that the fee-for-service concept is considered as relatively expensive (see also Section 4.2) and thus rather attracts the small segment of the population with a high income. Moreover, non-branded SHSs exist in different sizes so that very basic versions are also accessible for households that could not afford the user fee for a branded SHS. Overall, the two groups appear to be quite similar and, if at all, differ in terms of wealth, since users of branded products seem to be slightly better off than those of non-branded products.

4 Quality and cost of Solar Home Systems

4.1 Use and quality of electricity services

In this section we explore whether non-branded SHSs significantly differ in terms of their quality from branded SHSs that are alleged to be of higher quality. As a first indicator, we look at appliance usage to examine whether one type of SHS allows for higher usage intensity at the intensive margin than the other. Moreover, we put a particular focus on objective and subjective measures of lighting extent and quality considering that lighting is the major service households consume as they get access to electricity.

Table 2 shows TV ownership and the different lighting extent and quality indicators. Other appliances are not suitable for this assessment: they are either too uncommon with ownership rates among SHS users of below five percent or, as in the case of radios and mobile phones, widely used also in households without electricity access. The table differentiates between households without any SHS and those with an SHS and shows the differences between group averages and their significance level. Among users of non-branded SHSs, we again concentrate on those who purchased their SHS since 2009.[5]

A few non-adopters own a TV set run by car batteries, for example, or they watch TV with their neighbors. However, these figures are clearly lower than among electrified households. Table 2 shows that users of branded SHSs are more likely to own a TV set than users of non-branded SHSs but the difference of eight percentage points is relatively small (43 percent vs. 35 percent). Technically, owners of non-branded SHS are apparently able to use TV sets with their SHS. This is also underpinned by TV usage intensity, which is even slightly higher among owners of non-branded SHSs. It has to be remembered, though, that owners of branded SHSs tend to be wealthier

[5] The usage patterns do not differ considerably between households with non-branded SHSs acquired before or after 2009. The results would thus remain the same if we integrated early-adopting users of non-branded SHSs in these analyses.

than owners of non-branded SHSs, which may also be a reason for the higher share of TV owners.

Both owners of non-branded and branded SHSs illuminate about 1.8 rooms. Additionally, owners of branded SHSs use one outdoor lighting point that is installed by the service provider upon connection and thus benefit more extensively from exterior lighting than users of non-branded SHSs. Other lighting sources used are either powered by kerosene fuel (such as hurricane lanterns or traditional tin lamps), dry-cell batteries (LED lamps), or electricity (simple incandescent bulbs, neon tubes, or energy saver lamps). Also among non-adopters, candles are virtually not used anymore.

Table 2: Appliance ownership and lighting indicators

	Average indicator value			**Differences between group averages**		
	non-adopters	non-branded SHS (2009 or later)	branded SHS	non-branded SHS vs. non-adopters	branded SHS vs. non-adopters	branded SHS vs. non-branded SHS
TV						
TV ownership	0.05	0.35	0.43	0.30*** [0.00]	0.38*** [0.42]	0.08 [0.16]
Time household head watches TV per day, in minutes	15.6	51.5	47.0	35.9*** [0.00]	31.4*** [0.00]	-4.5 [0.58]
Lighting						
Number of rooms illuminated	1.53	1.89	1.78	0.36** [0.01]	0.25* [0.09]	-0.11 [0.50]
Number of bulbs used for exterior lighting	0.06	0.81	1.05	0.75*** [0.00]	0.99*** [0.00]	0.24*** [0.00]
Lighting hours per day	7.89	12.04	12.56	4.15*** [0.00]	4.67*** [0.00]	0.52 [0.63]
Lumen hours per day	1,090	8,300	6,510	7,210*** [0.00]	5,420*** [0.00]	-1,790** [0.02]

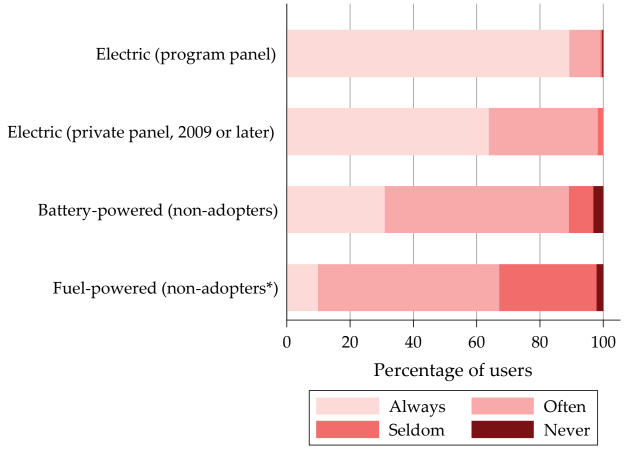
Note: Based on 772 weighted observations, *p*-values for group average differences in squared brackets. Stars indicate significance level with * p<0.1; ** p<0.05; *** p<0.01.

Our lighting quality indicators are lighting hours per day and lumen hours per day. Lighting hours per day is the number of all lamps used in the household, electric or not, times the average number of hours each one is lit throughout a typical day. Since this does not capture differences in the brightness of lighting sources, we also consider lumen hours per day. This implies multiplying the lighting hours per day with the average lumen value of the respective lamp type, summed up across all lighting sources a household uses.[6] Both types of SHS users consume 4.2 to 4.7 additional lighting hours as compared to households without SHSs. Users of branded SHSs do not consume significantly longer lighting hours than users of non-branded SHSs. This contrasts the comparison in terms of lumen hours: here, users of non-branded SHSs even consume significantly more. This is mostly due to the higher number of these households using neon tubes, which emit very high lumens under optimal conditions. However, we observed in the field that actual performance varies greatly, even among devices of the same lighting type, so we take this difference in lumen hours as being mostly suggestive. Neon tubes, for example, are often associated with flickering light.

As a more subjective measure of SHS performance, we look at households' satisfaction in terms of domestic lighting quality. This is shown in Figure 4. Satisfaction is measured in four categories: 'always', 'often', 'seldom', and 'never' satisfied. Users of the branded SHSs are clearly the most satisfied group. Close to 90 percent of them report being always satisfied, and almost none of them report being seldom or never satisfied. In contrast, only about 60 percent of the users of non-branded SHS reply to be always satisfied with their lighting. Still, more than 95 percent of owners of non-branded SHS state that they are either always or often satisfied. For non-adopters, the percentage of those always satisfied is significantly lower than half, at around 30 percent for battery-powered and below ten percent for fuel-powered lighting.

[6] Lumen values are taken from Nieuwenhout, van de Rijt, Wiggelinkhuizen, and van der Plas (1998), who coherently assessed both electric and non-electric sources of light in a laboratory experiment.

Figure 4: Satisfaction with lighting quality



Note: Based on 700 weighted observations. * Non-adopters have been split up into those using battery-powered lighting sources and those who don't and instead use fuel-powered lighting. Battery-powered lighting sources include mobile LED lamps, rechargeable lamps and hand-made battery-driven lighting devices. Fuel-powered lighting sources include traditional tin lamps, oil lamps, and hurricane lanterns.

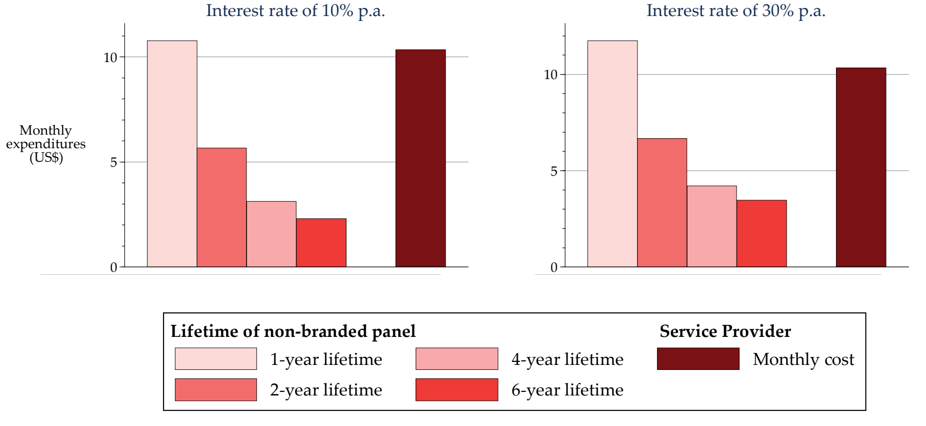
Source: Burkina SHS data set 2012.

Overall, either type of SHS users is significantly more satisfied with its illumination than households without an SHS. There is a difference in the perception of quality of branded and non-branded SHS, which seems to be of a similar magnitude than the difference between electric lighting of users of non-branded SHS and battery-powered lighting among non-adopters. However, these subjective statements also reveal that the quality of non-branded SHS is not much below the quality of branded SHS and hence these devices are not as bad as sometimes stated by proponents of branded solar products.

4.2 Comparative cost for current non-adopters

To go beyond a pure assessment of quality and performance, we now assess the cost-effectiveness of non-branded SHSs in comparison to the branded products. For this purpose, we have to make the investment into a non-branded SHS comparable to the monthly fee for branded SHSs. Specifically, the one-time purchase price plus potential repair expenditures have to be converted into a regular monthly payment over the lifetime of the non-branded SHS.[7] The SHS purchase price used in these calculations is based on the average price of SHSs purchased in the most recent years preceding our survey (2011 and 2012, see Figure 3) in order to account for the SHS price drop over the last decade. Average monthly repair expenditures in our data amount to 0.21 US$ per month. Since the SHS lifetime is a priori not exactly known, we work with alternative assumptions across the currently observed lifetime range of one to six years. A second decisive assumption relates to the discount interest rate used to calculate the regular monthly payment. In Figure 5, we compare results for a 10 and 30 percent annual interest rate.[8]

Figure 5: Cost comparison between non-branded and branded SHSs



Obviously, the fee-for-service offer becomes more attractive the more rapidly SHSs deteriorate. Yet, already with a lifetime of two years, non-branded SHSs are clearly less costly, irrespective of the chosen size of the interest rate used.

[7] The same would have to be done with the connection fees of the service provider over the subscription period. Since it is unknown, however, we abstain from doing so. Including the connection fees in the calculations would anyways only reinforce our results below, which suggest that the service provider is generally more expensive than non-branded SHSs.

[8] In a recent review of six experimental evaluations of microfinance products, Banerjee, Karlan, and Zinman (2015) report microlender interest rates between 12 and 110 percent.

For both branded and non-branded SHS effective costs additionally depend on whether users save on previous energy expenditures by adopting solar energy. Accounting for so-called *substitutable energy expenditures* (SEE) in the monthly payments determined above enables us to shed further light on the affordability of the SHS for customers in our sample. SEE include expenses for services that can in principle become dispensable when using SHSs: car batteries and dry-cell batteries, candles, as well as kerosene for lighting. Energy expenses not included in the SEE are, for example, those on cooking, since electric stoves cannot be operated with the SHSs. Empirically, we observe that even the SEE are not entirely replaced after SHS purchase, because households continue to use kerosene lamps in some rooms or add a second battery-powered radio, for example. Such fuel stacking is typical for energy transition processes in a developing country context (van der Kroon et al. 2013).

Against this background, we determine the additional financial burden of SHS uptake on households assuming that SEE decrease down to the energy expenditure levels that are empirically found among SHS users. Since energy expenditures and thus SEE may differ across income strata, we differentiate between income percentiles.[9]

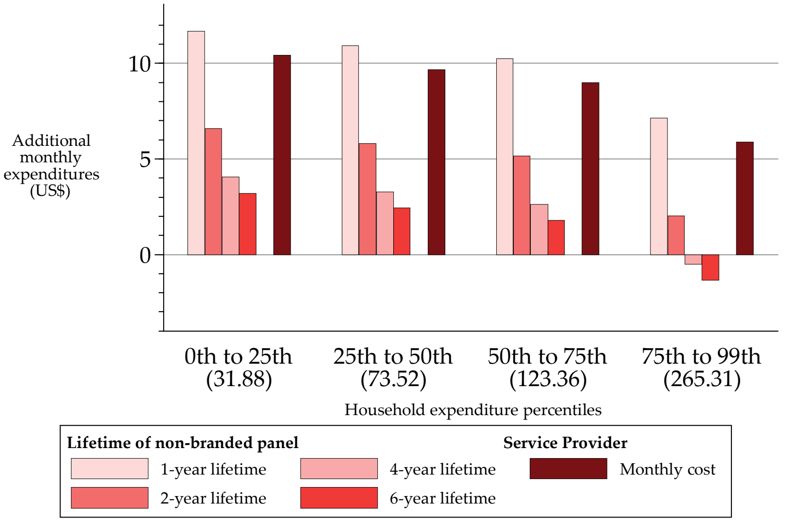
Figure 6 shows the results for this partial substitution scenario. Each bar represents the difference between monthly SHS cost and non-adopters' average SEE within a given quartile. The left set of bars refers to non-branded SHSs, the leftmost of these representing costs for an assumed SHS lifespan of one year, the rightmost for an assumed lifespan of six years. The bar on the right refers to the fees paid by households to the service provider.

Again, non-branded SHSs are, on a monthly basis, cheaper than the user fee of branded SHSs if the non-branded SHSs last for at least two years. Still, even assuming a four-year term, households in the third quartile of the expenditure

[9] We use household expenditures as a proxy for income. To avoid that outliers bias our results, the top percentile of the expenditure distribution is excluded, which, however, does not affect our results.

distribution for instance would have to accommodate expenditures equal to 2.1 percent of their total monthly expenditures if they purchased a non-branded SHS. Most current non-adopters would have to increase their monthly energy expenditures if they acquired either type of SHS. These expenditures as a share of total expenditures would be higher for shorter lifespans and lower quartiles. For a lifespan of two years, the lowest two quartiles would need to spend 21 and 8 percent of their expenditures, respectively.

Figure 6: Expenditure effects of SHS adoption under partial substitution



Note: Based on n = 880 observations. Average monthly household expenditures in US$ within each quartile are given in parentheses.

Source: Burkina SHS data set 2012.

Figure 5 and Figure 6 allow for another insightful reading when reinterpreting the depicted SHS lifetimes as credit periods granted for a loan to acquire an SHS. While the graphs do not change, the additional monthly expenditures now reflect monthly loan repayment amounts assuming the annual interest rates used above of 10 and 30 percent. In their recent review of microfinance studies, Banerjee et al. (2015) do not report terms exceeding 24 months, with most lenders allowing one year for repayment. Thus considering again a two year credit period in Figure 6, households would likely have to spend around 2 to 6.5 US$ each month to repay their non-branded SHS. Remember that for the lowest income quartile, this would be equivalent to 21 percent of their monthly expenditures.

Two broader points emerge from these scenarios. First, under realistic assumptions, the adoption of an SHS will come with an overall increase in monthly energy expenditures. Yet, this increase implies of course also a higher service level. As discussed in Section 4.1, lighting extent and quality are higher among SHS users and additional appliances can be used and are actually used, which seems to justify the additional costs from the individual households' perspective. Second, non-branded SHSs sold at market prices tend to be substantially cheaper than branded SHSs rented via the service provider. Already after about 1.5 years, the fees accumulated for the branded SHSs exceed the costs of the non-branded SHSs. It is important to keep in mind, however, that even if non-branded SHSs are cheaper, branded SHSs may still be preferred by households that appreciate the after-sales services. The cost difference might also be somewhat smaller for branded SHSs that are bought and not rented. Yet, what is crucial in terms of sustainability is that non-branded SHSs are used without special promotion efforts and that they are cost-effective in the sense that they generate a positive return.

5 Conclusion

We presented data on solar home system (SHS) ownership in rural Burkina Faso. Around four years prior to our survey a local company had started marketing branded SHSs via a fee-for service approach. Our first insightful finding is that SHSs had already been available and intensely used in the survey region before this donor-supported dissemination program started. Such considerable penetration rates for non-branded solar products are nowadays observed in many rural areas in Africa. At the same time, branded solar products are frequently promoted as being a more sustainable off-grid solution. Against this background, we compared the performance of those branded and non-branded SHSs based on our data. With the caveat in mind that these two user groups for various reasons are not perfectly comparable, we observe that differences in adopter characteristics are not very pronounced and also differences in SHS quality are rather small, both when looking at objective and subjective criteria. Moreover, non-branded SHSs are considerably cheaper than the branded SHSs distributed via the fee-for-service approach if likely lifetimes of at least four years are considered.

Our findings present an insightful case study about developments and dynamics in off-grid solar markets. It is often argued that these markets do not function sustainably in the absence of promotion programs or at least regulatory interventions. Various reasons are brought forward including low profitability on the supply side and weak demand due to low purchasing power, but also related to quality standards (Lighting Global, 2016). Non-branded products, so the argument goes, are cheaper but of substantially inferior quality, which is invisible for the customers. It is then argued that the market is at risk to fully disappear as in Akerlof's well-known example of a "market for lemons" (Akerlof, 1970), i.e. the quality of SHSs traded would degrade in the presence of information asymmetry between buyers and sellers, leaving eventually only low quality SHSs behind. We do not find any indication for such a market of lemons.

Also note that Burkina Faso is one of the poorest countries in the world and our survey region is quite typical for its impoverished rural areas. If it were generally the case that supply and demand-side constraints were holding back SHS diffusion, the problem should be especially severe in this part of the world. While of course only relatively wealthy households in our sample are able to acquire non-branded SHSs, this is likewise true for branded SHSs promoted by an internationally supported program. In fact, our comparison of SHS adopters and on effective expenditures with and without SHS acquisition suggests that non-branded solar products are even in a better position to serve lower income groups than branded products.

The conclusions drawn from this also need to acknowledge that the solar market has seen important innovations in terms of technologies and business models since our data was collected in 2012. Most notably, plug-and-play pico-solar systems smaller than 10 Watt, highly efficient devices including TVs and fans as well as pay-as-you-go and results-based-financing schemes have made off-grid solar much more accessible to poor households (Lighting Global, 2016; Guajardo, 2016). Not least, the service provider assessed in this study went bankrupt three years after data collection. For these reasons, industry representatives rather see the role for public agents in facilitating market development through industry-wide mass consumer education and awareness-raising campaigns and harmonized quality standards (GOGLA, 2015).

The observations remains, nevertheless, that the donor-backed outlets with cost-covering prices do not seem to have provided large benefits over already existing markets in the area we study. If the goal of interventions in SHS markets is to provide access to electricity to the most disadvantaged and thus the poorest strata of society, also smart financing schemes such as pay-as-you-go might not be sufficient (see for example Collings and Munyehirwe 2016). Prices must be affordable to the poor and hence need not necessarily be cost-covering – at least in the short and medium term. Against the background of universal access goals, our affordability examination in the previous section makes an argument for such subsidies. Alternatively, long-term financing schemes might be helpful along the lines proposed by Abdullah and Jeanty (2011), for example. However, interest rates would need to be substantially lower and loan terms substantially longer than what is usually found in practice. More common short-term loans are likely not going to be sufficient to make non-branded SHSs truly attractive to poor households. From an energy-access perspective, however, there is little reason to center such might be justified by a life-cycle management argument: the surging consumption of off-grid solar including harmful lead-acid batteries in rural Africa is leading to increasing volumes of electronic waste, which is becoming a growing environmental burden. It might indeed be more feasible to implement a reasonable waste management system financing schemes on branded products. Instead, public support through licensed vendors on local markets or in local shops than through non-licensed ones.

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Appendix A: Descriptive statistics

Table A.1: Descriptive statistics for variables of interest

	Mean (Standard deviation)					*n*
Variable	full sample	non-adopters	non-branded SHS (before 2009)	non-branded SHS (2009 or later)	branded SHS	full sample
Household size	8.00 (4.01)	7.52 (3.84)	7.99 (3.41)	8.70 (4.06)	9.62 (5.32)	879
Polygamous household	0.553	0.484	0.62	0.643	0.677	880
Age of head of household (years)	43.93 (11.99)	44.56 (12.36)	42.44 (10.78)	43.05 (11.41)	44.81 (12.99)	874
Head of household is a subsistence farmer	0.925	0.927	0.898	0.942	0.917	879
Head of household has a formal education	0.283	0.261	0.311	0.329	0.264	864
Household receives remittances	0.013	0.015	0.000	0.015	0.015	876
Head of household has an account at a bank or savings institutions	0.162	0.115	0.278	0.188	0.191	880
Distance to next service agency (km)	16.54 (17.02)	15.00 (15.45)	23.44 (21.99)	16.52 (17.21)	13.39 (11.34)	880
Monthly household expenditures excluding energy (US$)	162.06 (168.63)	127.93 (156.07)	208.35 (150.31)	195.86 (178.14)	222.21 (207.07)	880
Asset index	0.00 (1.00)	-0.36 (1.03)	0.59 (0.67)	0.36 (0.81)	0.42 (0.75)	878
Number of observations	880	332	108	135	304	

Note: *n* refers to the number of observations for each variable. Observations are weighted. Standard deviations are not reported for dummy variables.