Energy for Sustainable Development 60 (2021) 33–39

Contents lists available at ScienceDirect

Energy for Sustainable Development

Using a choice experiment to understand preferences in off-grid solar electricity attributes: The case of Nigerian households

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ARTICLE INFO

Article history:
Received 20 May 2020
Revised 30 November 2020
Accepted 1 December 2020
Available online 16 December 2020

Keywords:
Energy preferences
Choice experiments
Consumer preferences
Solar energy
Off-grid solar electricity
Rural electrification
Sub-Saharan Africa

ABSTRACT

One of the pressing challenges to economic development in sub-Saharan Africa (SSA) is access to electrical power. In Nigeria, there is a large gap in electricity access between rural and urban areas; only about 40% have access in rural areas as compared to almost 60% in urban areas. A potential solution is the use of off-grid solar electricity to meet their needs. This article seeks to assess the tradeoffs involved in using off-grid solar electricity from the perspective of Nigerian households. Given their generally low income levels, the research focuses on the lower end of the market for off-grid solar electricity: solar chargers. It uses choice experiments to measure households' preferences for solar electricity by exploring attributes rural households are looking for in solar chargers. The relationship between households' preferences and off-grid solar electricity was analyzed using a random parameter logit model. Findings indicate that confidence in the quality of the product was the most important variable, and that respondents associated higher priced solar chargers with higher quality. These findings suggest that energy companies making off-grid electricity technology could consider offering warrantees for high-quality products in order to build consumers' trust.

Published by Elsevier Inc. on behalf of International Energy Initiative.

Introduction

Energy poverty is a major problem facing households in developing countries. Worldwide, only 13% of people globally lack access to electricity, but three quarters of them – about 580 million people – live in sub-Saharan Africa (International Energy Agency, 2020; International Energy Agency, I, 2017). These people depend on polluting fuels for heating and lighting that are hazardous to health and safety, and that contribute to global greenhouse gas emissions (Trotter, 2016; UNDP, 2015). Access to electricity is vital for economic and social development of households, bringing benefits such as improved health and healthcare services, education and productivity. With this in mind, the United Nations included access to affordable and clean energy for all by 2030 as one of its sustainable development goals (Emili, Ceschin, & Harrison, 2016; UNDP, 2015).

Nigeria is home to about 80.1 million people without access to electricity (International Energy Agency, 2020). There is unmet demand, inadequate supply, and underutilization of the electric grid. The existing infrastructure provides only about 14% of the estimated demand (Nigerian Electricity Regulatory Commission, 2018; Sambo, 2008). According to the Nigerian Electricity Regulatory Commission (NERC), only about 49.5% of the capacity of the country's power plants were utilized in 2018, due to problems with gas supply, distribution and transmission (Chidebell-Emordi, 2015). This underutilization of the national capacity for electrical power generation causes electricity to be rationed, inconsistent, and subject to partial and systematic collapse of the grid. For instance, in the third quarter of 2017, the country experienced one total system collapse and four partial system collapses (Ikeme & Ebohon, 2005; Nigerian Electricity Regulatory Commission (NERC), 2017).

Adeoti, Oyewole, and Adegboyega (2001) noted that the Nigerian government has sought to improve the problem of insufficient supply of electricity by updating the current infrastructure, extending grid lines to rural areas, and meeting electricity demand (Adeoti et al., 2001). The government invested over $16 billion from 1997 to 2007 to improve and expand power genertation; however due to corruption and mismanagement of funds, the problems still persist (Aliyu, Ramli, & Saleh, 2013). The NERC also generates revenue that can be used to address the power problems, but the revenue collected nationwide is only 55.3% of the total billed (Nigerian Electricity Regulatory Commission (NERC), 2017), and the majority of the revenue collected is used for administrative costs (Aliyu et al., 2013).

To fill the gap between supply and demand, households and businesses have resorted to the use of home generators, kerosene lanterns, candles, and battery-powered flashlights for lighting and other electrical needs. However, some households cannot meet their electricity needs, so they are left without alternatives. Furthermore, shortage in

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https://doi.org/10.1016/j.esd.2020.12.001
0973-0826/Published by Elsevier Inc. on behalf of International Energy Initiative.

electricity supply leads to businesses operating at higher cost to meet their demands, and it limits the number of new businesses entering the market. Therefore, there is a loss in economic opportunities, and higher operating costs are passed on to household consumers (Oji J. et al., 2012).

Therefore, there is a need to explore alternative ways of meeting the electricity needs of the Nigerian population that are cost effective, economically viable, consistent and environmentally feasible. One option that can be used to address the energy deficit in Nigeria is the use of solar energy, because of its enormous potential (International Energy Agency, 2019). For instance, in Nigeria, if 5% of the available solar energy were converted, it could generate about 4.2×10^5 Gigawatt/hour (GW/h) of electricity, which would meet the country's demand and would be 26 times more than the electricity production from the grid (Ogunleye, 2011; Oyedepo, 2012). Off-grid options like photovoltaic (PV) systems and solar panel chargers are attractive options in addressing rural and urban energy needs because they can offer small amounts of electrical power that may potentially contribute to lighting, mobile phone and laptop charging (Adurodija, Asia, & Chendo, 1998). They also have low maintenance costs because they are durable and require no fuel. They can meet the basic energy needs of a household (Adeoti et al., 2001).

Despite this potential for solar systems to meet the demand for electricity, Nigerian households have been slow to adopt such technologies. One reason is the cost of PV systems; 80% of households live below the poverty line and the average cost of PV system exceeds the amount of money that they earn in a year. There are also other challenges and barriers like installation and access that households face in adopting PV systems (Hancock, 2015; Karakaya & Sriwannawit, 2015). Because of these constraints, we focus on the lower end of the market for off-grid solar electricity: solar chargers.

A solar charger is a portable panel that can produce small amounts of electricity to households, enough to power and charge mobile phones during the day, and small electronics like radios and rechargeable lamps that can be used in the evening. Even though solar chargers supply only a small quantity of electricity, they can greatly improve the quality of life by, for example, making it easier and safer to light the home at night. In particular, a solar charger can recharge a rechargeable electric lamp, which provides ongoing reliable light for several hours, as opposed to using kerosene, which provides only dim light and pollutes the indoor air. A rechargeable lamp is also far more convenient than a flashlight or the light on a mobile phone.

Solar chargers also provide convenience; for example, they save households time and money because they do not have to go out to charge their mobile phones with street vendors. In addition, if households have solar chargers, they do not have to depend on their neighbors who own generators for electricity or constantly buy batteries for their small electronics. The price of solar chargers ranges from $28 to $54 (in US dollars), with varying levels of charging capacity (Jumia Nigeria, 2018).

Consequently, we estimate the household demand for electricity in the context of off-grid solar electricity in Nigeria, specifically for relatively inexpensive solar chargers. Given the relatively low average level of income, we wanted to understand tradeoffs households are willing to make for the solar charger. This study uses discrete choice experiments to understand households' preferences for solar electricity by exploring attributes rural households value in solar chargers. We quantify the various attributes of interest and estimate demand from individual characteristics of solar electricity. The study also examines the effects of information on households' willingness to purchase solar electricity.

Study area

The data used in this study are derived from a household survey conducted with adult respondents in four different communities in Ayetoro, Yewa north local government, Ogun State, southwest Nigeria. These communities are Idagba-Olorunsogo, Oke Oyinbo, Oke Joga, and Saala. The communities were chosen because of their blend of rural and urban households (they are peri-urban). They are also close to a state university and a federal government clinic, so the households interviewed had a blend of students, families and seasonal workers.

This study was motivated in part by findings from a previous survey conducted in July 2017 covering the same population and focusing on household energy use (Elegbede, 2019). The previous survey found that the majority of respondents were connected to the electric grid, but they only received power 3 h per day on average. They experienced blackouts every day, and sometimes for days at a stretch. It was difficult to estimate the amount of time households had power because they only received power randomly throughout the day. In addition, when they had power, it was not always stable. The households experienced electrical damage to their appliances because of intermittent delivery from the grid.

In the previous survey, respondents expressed concerns with solar power. Some believed that when it rains, the solar power will not work. Another big issue is the amount of solar technology on the market that does not work efficiently or breaks down in a short amount of time. As a consequence, people expressed distrust in solar energy technologies. However, they also expressed willingness to adopt solar electricity if it is available, reliable, affordable, and properly explained.

These findings in the previous survey motivated the follow-up study to examine conumers' preferences regarding the characteristics of solar technologies.

Methods

Modeling preferences for off-grid solar electricity using choice experiments

The theoretical foundation of the study is based on Lancaster consumer theory, which provides the basis for discrete choice experiments (Lancaster, 1966). This approach assumes that utility is derived from the properties and characteristics of a good, and it assumes the consumption of a good as an activity that produces an output that is a collection of characteristics (Lancaster, 1966). The good in this instance is off-grid solar electricity. The good possesses energy characteristics, and environmentally-friendly characteristics in that the generation of solar energy does not contribute to emissions of greenhouse gases, such as carbon dioxide (CO_2). This approach allows allocating the collection of characteristics with the use of off-grid solar electricity. This contributes to the analysis when trying to distinguish various consumers' reactions to prices, attributes, and applicability (Lancaster, 1966).

Choice experiments (CE) are used to understand how decision makers will hypothetically make choices to adopt new technologies (Waldman, Ortega, Richardson, & Snapp, 2017). In this instance, the focus is on how consumers will choose between technologies that generate solar electricity. CE is grounded in consumer demand theory, and the assumption is that the decision makers are rational, and they aim to derive satisfaction or utility from their choices (Mankiw, 2008), relative to the alternatives. Here, utility is defined as the level of happiness a person derives from his or her circumstances; it is a measurement of well-being (Mankiw, 2008). It is also assumed that the decision-makers aim to derive optimal satisfaction. Therefore, the decision makers seek to maximize their utility, with the assumption that they will always choose the most preferred good that is affordable (Varian, 1992).

In a choice experiment, households are presented with sets of alternative combinations of attributes of off-grid solar electricity, and they are asked to choose their most preferred alternative. The data from the experiment reveals the trade-offs households are willing to make between attributes of off-grid solar electricity. The choices presented to households are modeled as a function of the attributes using random utility theory, based on individuals making choices on characteristics randomly (Scarpa & Willis, 2010).

Theoretically, consumers are assumed to maximize utility resultant from their decisions, given a budget constraint. The utility from individual choices is derived from two parts. The first part is the explainable variable that comprises the attributes of the good and the characteristics of the individual. These will be classified as *Vij*, where V is the variable, *i* is the individual and *j* is the choice (Lancsar & Louviere, 2008). The second part is the non-explainable variable, unobserved attributes, measurement error or random component, classified as *εij*. Therefore, the utility (U) an individual gets from choices can be expressed in equation form as:

$$Uij = Vij + \varepsilon ij \tag{1}$$

Vij is the systematic component that is a function of attributes and characteristics, it is modeled as:

$$Vij = X`ij\,\beta + Z`i\,\gamma \tag{2}$$

where $X`$ is a vector of choice experiment attributes and socio-economic characteristics; β is the coefficient to be estimated and corresponding parameter for the $X`$ vector; $Z`$ is a vector of characteristics of individual *i*; and γ is the coefficient to be estimated and corresponding parameter for $Z`$ (Bennett & Birol, 2010; Lancsar & Louviere, 2008). Utility is comprised of observed and unobserved consumer satisfaction; it is a latent variable. Hence, it is assumed that an individual will make a choice if, and only if, their utility from that choice is higher than utility from other choices in a set of *J* alternatives (Bennett & Birol, 2010; Lancsar & Louviere, 2008). The probability *P* of the choice being 1 that maximizes utility can be expressed as:

$$\begin{aligned} P\,(Yi = 1) &= P\,(Ui_1 > Uij) \\ &= P\,(Vi_1 + \varepsilon i_1 > Vij + \varepsilon ij)\ (*\text{Note } Uij = Vij + \varepsilon ij) \\ &= P\,(Vi_1 - Vij > \varepsilon ij - \varepsilon i_1)\ (j \neq 1) \end{aligned} \tag{3}$$

Estimable choice models are derived assuming the errors are independently and identically distributed (IID). However, where an individual is allowed to make a choice given alternatives to choose from since households make repeated choices, the assumption of independence may be violated, since the choices might be correlated. Also, households are a heterogenous group whose preferences for off-grid solar electricity characteristics may also be heterogenous.

Therefore, the error term can be specified as.

$$\varepsilon ij = uij + vij;\ uij\tilde{N}(0, \sigma 2\,),\ vij\tilde{N}\ (0, \sigma 2) \tag{4}$$

where the u is the unobservable effects and v denotes the remainder disturbance; both being normally distributed (Bennett & Birol, 2010). A mixed logit model, also called random parameters logit (RPL), was used to evaluate the heterogeneity of preferences (Hensher, Rose, & Greene, 2015). This choice modeling allows for the IID assumptions to be relaxed and considers different decision making of households.

Research design

Based on the information presented above, the following attributes were selected for use in the choice experiment: price, hours, power, and country of manufacture. The price of off-grid solar electricity is a concern in Nigeria as elsewhere (Adurodija et al., 1998). Though the price has dropped over the years, compared to other energy sources the cost of off-grid solar electricity is generally higher (Kabir, Kumar, Kumar, Adelodun, & Kim, 2018; Sarzynski, Larrieu, & Shrimali, 2012), but they are still relatively expensive for people in the study area. The price range used in the experiment for solar chargers was determined from market and online prices in Nigeria (Jumia Nigeria, 2018).

The price coefficient in the analysis of choice experiment data tends to be negative, as a fundamental tenet of economic theory: given two otherwise equal choices, people will choose the one that is less expensive. However, literature in psychology shows that this is not always the case – that people often assume that a higher price means higher quality, and so therefore they choose the more expensive product in the absence of other information (Blood, Zatorre, Shiv, & Rangel, 2008; Smith & Broome, 1966; Zeithaml, 1988). Other studies also confirm that when consumers that do not have enough information on a product and cost to access information is also high, they will infer that a higher-priced product is of higher quality (Bagwell & Riordan, 1991; Chan & Leland, 1982). This will be further addressed later in the discussion section.

Based on the off-grid technology prices and specifications we were able to estimate the number of hours the technology can be used for. For the solar chargers we explained to the respondents that they can be used only during the day time. (Of course, the small appliances that they charge can then be used any time.) The hours were also informed by the average amount of time households got electricity from the grid. We wanted to explore the tradeoffs between current grid and off-grid solar electricity.

The attribute of power demonstrates the amount of wattage households can get from off-grid solar electricity. Since it will be difficult for households to understand power in wattage terms, pictures were used to depict the number of mobile phones the chargers could charge as a proxy for power (see Fig. 1 for example). More mobile phones imply a more powerful system.

The final attribute for the experiment was the country in which the solar chargers were manufactured. From the previous energy survey, respondents expressed a lack of trust in solar technology, and the country variable is intended to address the importance of trust (Elegbede, 2019). In particular, in Nigeria, products manufactured in China are considered to be of relatively low quality. On the other hand, it is common knowledge in Nigeria that people perceive products made in the United States to be of higher quality, and they expressed that in the energy survey. Accordingly, in the choice experiment, the choice of country serves as a proxy for trust, in order to estimate the price premium that people would be willing to pay for products they trust more. (See Table 1).

Design of choice sets

For the experimental design, a set of profiles were constructed, and we used Ngene software to create an orthogonal design with attributes and levels (Lancsar & Louviere, 2008; Ortega, Waldman, Richardson, Clay, & Snapp, 2016). For each product, the design considered attributes and their various levels. For solar chargers, there are four attributes considered: three attributes with three levels and one attribute with two levels. This gives $3^3 \times 1^2$ (=27) possible profiles. For each product, a total of 18 choice tasks were generated and blocked into 3 groups of 6 choice scenarios. Respondents were only presented 6 scenarios instead of 18, to avoid fatigue and to collect more reliable data. An option to opt out was available to respondents for each choice task (see Fig. 1 for an example; the attributes and levels in this example are drawn from Table 1). The opt-out option (Option C) is for respondents not interested in acquiring off-grid solar electricity. A booklet was created for each block, each containing 6 choice sets. The choice tasks were demonstrated and presented to households. A trial run was conducted to ensure the tasks were understood and applicable to the respondents. The currency was Naira in the choice tasks but it has been converted to USD in the analysis.

Data collection and questionnaire

The households were interviewed between April and May 2018; the sample consisted of 312 randomly selected respondents. This information guides the design of the choice experiment presented in this paper. The previous survey included an energy audit of the amount of energy people use, its sources, and how much they spend. It also focused

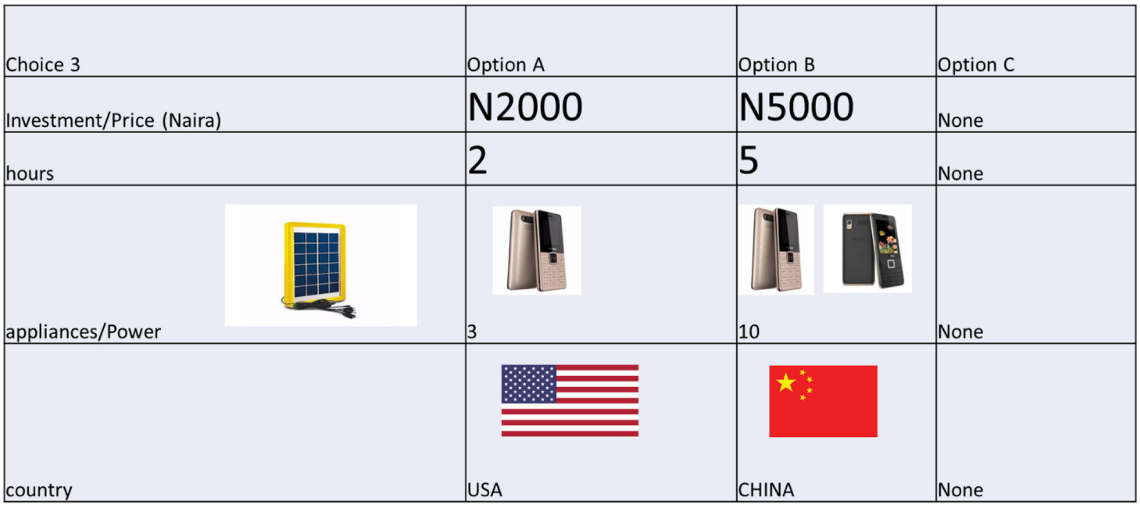

Fig. 1. Example of choice task for solar chargers.

on people's experience with electricity from the grid and perceptions of solar technology.

The survey was conducted in English with two enumerators. The survey instrument was subdivided into five sections. The first section was dedicated to the demographic information, including age, marital status, occupation, income per week, and house ownership. In the second section, people were asked about various ways they access electricity to charge their mobile phone and if they paid to charge their mobile phones. (The survey focused on mobile phones for the sake of simplicity, even though the chargers can be used to recharge lamps and other small appliances.) The third section was open-ended; we asked respondents about alternative ways they met their electricity needs and the cost associated with it, and they provided responses in their own words. It investigated the use of generators and fuel spent per week to power them. The fourth section was devoted to the choice experiment. The choice tasks were presented to the households after a detailed explanation of off-grid solar electricity and the various attributes of the chargers. Photographs of each attribute were presented; respondents had the option of opting out (not choosing any of the options) and they were asked their reasons for opting out. The fifth section was used to gauge the confidence of households in off-grid solar electricity; in particular we wanted to know how much households trusted the technology and the reasons for their trust or distrust. People were asked to state on a rating scale ranging from 1 (least confident) to 10 (completely confident) if off-grid solar electricity was worth spending money on. A follow up open-ended question was asked to gain insight on their responses to the rating scale. The completion of the questionnaires took about 20 min. A total of 312 completed questionnaires were collected from households for solar chargers. In addition to the survey data, enumerators recorded comments that respondents made regarding their opinions and impressions of solar chargers. We use quotes from the respondents to support conclusions of the econometric analysis.

Table 1
Attributes and Attribute Levels in the Choice Experiments for Solar Chargers.

No	Attributes	Description	Attribute Levels
1	Price	Initial Investment (Upfront cost)	\$28.33, \$39.66, \$53.82
2	Hours	Amount of time in hours it can be used for	2, 3, 5
3	Power	Wattage for solar chargers	3, 10, 15
4	Country	Country where product is manufactured	United States, China

Estimation

The objective of the research is to understand households' preferences regarding off-grid solar electricity. We use the parameter estimates of attributes obtained from the random parameter logit (RPL) models while holding all else constant (Hensher et al., 2015). The coefficients obtained from the RPL models represent households' preference or marginal utilities for each of the attributes (Waldman et al., 2017). The samples for the experiments for solar chargers were analyzed with NLOGIT software. For the RPL model, we applied 1000 Halton draws to investigate the preference heterogeneity amongst households and the utility formula was applied to the model.

$$U(alt1) = \beta_{price}\,Price + \beta_{hours}\,Hours + \beta_{watts}\,Watts + \beta_{country}\,Country \quad (5)$$

$$U(alt2) = \beta_{price}\,Price + \beta_{hours}\,Hours + \beta_{watts}\,Watts + \beta_{country}\,Country \quad (6)$$

$$U(alt3) = Opt\ out \quad (7)$$

Price is a continuous variable indicating the extra cost of acquiring solar chargers. Hours is a continuous variable that indicates the number of hours a household can use the technology for. Watts is a continuous variable that indicates the amount of power households can get out of solar chargers. Country is a dummy variable indicating country of manufacture for the solar technology (Value 1 United States, 0 China). The last alternative is the utility for those that opted out, i.e. who did not express preference to purchase either alternative.

Results

This section first presents summary statistics from the survey and then the choice experiment results.

Summary statistics

Table 2 provides descriptive statistics of the households in the survey. In the survey the majority of the respondents earned less than \$14.16 per week, which is about \$2 per day. Over 60% of the households were renting their home. The average respondent was about 34 years of age with about 14 years of formal education. Nearly half of the sample were between the age of 18–30, which is reflective of the young Nigerian population. A little over half of the respondents in the survey were married (57.3%).

Table 2
Socio-economic characteristics of the sample ($n = 312$).

Characteristics	Percentage of people
Married	57.3%
Dwelling	
Rent	62.5%
Own	37.5%
Weekly income	
$0.00 - $14.16	39.4%
$14.16 -$42.49	30.1%
$42.49 -$70.82	18.6%
Above $70.82	11.9%
Age	
18–30	46.5%
31–40	19.9%
41–50	22.4%
51–77	11.2%

To understand the means by which households access electricity, in the survey we used mobile phone charging as a proxy for electricity use. It provides an understanding of how they adapt to the inconsistency and shortage in electricity supply. A majority of households reported they charged their mobile phones at home; however, due to the power inconsistencies most of them used petrol-powered generators to charge their phones. Households reported that those who cannot afford generators or petrol may seek to charge their phones for free, for example, at a neighbor's house or at work, school, or local businesses like barber shops, hotels and gas stations. Sometimes if neighbors are unable to provide electricity, they go to businesses that provide electricity at a price. Only 8.4% of the total sample reported that they pay others to charge their mobile phones; the average cost they spent on charging was equivalent to $0.27 per charge. Such people only charge their phones twice a week and it is off after the battery runs out or the phone is turned off much of the time in order to avoid having to charge it every day.

According to our results, the average confidence rating in the solar charger was 7.1 out of 10. People were particularly concerned about whether or not the product came with a guarantee. They were willing to consider a product if it came with a warranty/certification. Most electronic products sold in the markets have a "no return" policy; therefore, consumers must perform as many tests as possible at the point of sale. Some people still felt less confident because of lack of trust with the sellers of the technology. People expressed concerns with durability based on their negative experiences with solar products that are similar in size with solar chargers. A respondent from Idagba-Olorunsogo said:

> "Dealing with electronics is a game of chance. It may or may not work."

Another respondent from Oke Oyinbo said:

> "I've used a few of these chargers and the problem with them is the short lifespan. My confidence is halfway."

In contrast, some felt more confident that solar chargers would work because they have seen off-grid solar electricity used by their families and by the state government to power street lights, and the fact it was powered by the sun. In addition, some people reported seeing their neighbors or friends using the product. A majority of respondents thought off-grid solar electricity would serve their electricity needs and save them money as compared to power from the electrical grid and generators. The same sentiment applied to solar chargers.

Many respondents attributed a higher price as signaling higher quality. A respondent from Oke Joga gave a direct and brief quote:

> "For spending such high amount of money, it has to work."

This was a very common sentiment in the open-ended discussion. Respondents felt a higher price of certain solar charger models was an indication that they would work properly.

Choice experiment results

The results from the solar charger choice model are reported in Table 3. Looking at the RPL results, the only coefficients that are significant are price and country. The price attribute is positive, meaning that the higher the price of solar chargers, the higher the propensity that people want to choose them. Although this is not the norm in choice experiments, it is consistent with the idea that people associate price with quality and that they don't want to buy something that will break. It will be discussed further in the discussion section below.

With respect to the country in which solar chargers are manufactured, people prefer if the solar chargers are manufactured in the United States as compared to China. A respondent from Idagba-Olorunsogo, reflecting a commonly held sentiment, said:

> "Chinese products have low quality and don't last as long"

The observations where the opt-out option was chosen indicate a rejection of either option, and thus no preference for purchasing a solar charger under either of the two alternatives. These results suggest that these respondents were either unfamiliar with solar chargers, uninterested in purchasing such devices, or unable to purchase the products because they were unaffordable. The provision of a warranty or some sort of certification as an option in choice experiment could perhaps increase the willingness of respondents to indicate a preference for solar chargers, and this could be a subject for future research.

Hours and watts are both insignificant in the table, indicating that the size of the system and the number of hours per day it can be used are not important variables for the respondents.

Discussion

There is a shortage of electricity in Nigeria along with inconsistent supply from the electrical grid. Households are heavily dependent on generators and other means to meet their electricity demand. From the survey, close to 50% of the households sampled own generators. However, there is still demand for more and cheaper sources of electricity, which off-grid solar electricity can help to meet (UNDP, 2015). Nevertheless, there are challenges that households face. The obvious challenge is the affordability of off-grid solar electricity given their income. In the sample about 40% of the households reported income of less than $14 per week. This demonstrates how challenging it will be for households to purchase off-grid solar electricity.

Overall, household respondents expressed concern with the quality of the products in the market. Since there are no warranties on products, based on their bad experiences buying products that malfunction or do not last, households felt cheated and cynical about their alternatives for sources of electricity.

Table 3
Random parameter model results for solar chargers.

	Preference space	
	Coefficient	Std. error
Price	0.01942*	0.01069
Hours	0.04934	0.03828
Watts	0.01216	0.00772
Country	0.53076***	0.15501
Opt-out	−5.00189***	0.24140
Model fit statistics		
N		1871
Log-likelihood		−1180.59
AIC		2377.2

Note: ***, **, * represent significance at the 1%, 5%, and 10% levels. Multinomial.
Logit model estimated using NLOGIT 5.0 based on 1000 Halton draws used for simulated Maximum likelihood.

The choice experiment (CE) was designed with households' income levels taken into consideration, so that we could understand households' preferences for small-scale solar technology, such as solar chargers. In the CE results, trust or confidence in the quality of the charger was the most important variable as households in our sample preferred chargers made in the United States to those made in China because of perceptions about product durability.

Households also associated higher priced solar chargers with quality and thus chargers they could trust more. The results show that they expressed preference for the higher priced charger over the lower priced unit. This result is critical because the prices of solar chargers are between $28 and $54 and a majority of the households earn less than $42 a month, so the products are expensive but affordable for their income range.

As mentioned above, multiple studies have shown that people often will prefer to pay more, despite the notion in economic theory that when offered two otherwise identical products, people will choose the cheaper one. For instance, in a study involving wine varieties, researchers found that as the price of wine increased the expectations of consumers increased also, implying that they considered the more expensive wine as better quality (Blood et al., 2008). Another study drew similar findings in testing the effects of pricing on consumer behavior; consumers found more benefit from products priced higher, controlling for other factors (Shiv, Carmon, & Ariely, 2005). This suggests that in our study, since the households are not completely familiar with the product and brand, they use price as a cue for the quality and attribute higher quality to price. In addition, because of their negative perception of solar products on the market and the risk of products not working, households tended to select a higher priced product (Zeithaml, 1988). This behavior is entirely consistent with the psychology and marketing literature.

The econometric results are also supported by the qualitative responses. Respondents frequently expressed frustrations with defective products that led to reduced trust in solar chargers. In addition, some of them expressed the expectation that a more expensive product would be of higher quality, thus increasing their trust. A future study of preferences for solar chargers and other off-grid solar electricity products could include a warranty or certification as a choice attribute, to determine if this may influence respondents' choices.

Conclusions

Nigeria's electrical grid reaches about half the population, and the electricity supplied is inconsistent and inadequate. The alternative source of electricity is petrol-powered generators, which are not affordable to most households, and require daily refeuling. With off-grid solar electricity households can have direct access to electricity and can transition into cleaner and renewable energy source. However, it still faces significant barriers to adoption by households. In some instances, it may be more appealing to households with lower income and energy needs, but the lack of trust in solar power is a deterrent. However, there is potential value in small-scale solar chargers because they provide a cost-effective way to meet basic electricity needs.

These findings have implications for energy companies that produce and sell off-grid electricity technology; contributing to product design, pricing policies and market segmentation of households in Nigeria. Households are very concerned about the quality of the product. Energy companies that are offering a high-quality product could consider providing warranties and more information about the product.

The findings can also contribute to the rural electrification policy for Nigeria. The policy seeks to increase electrification of rural households and also add renewable sources to the energy mix. The Standards Organization of Nigeria (SON), which is responsible for quality control, certification and circulation of information around solar systems can use the findings to ensure quality products are introduced to market. This can reduce the number of defective products on the market while increasing the trust of households in this technology.

Ethics approval and consent to participate

This study received approval by Michigan State University's Human Research Protection Program. IRB# x17-878e.

Consent for publication

Not applicable.

Availability of data and material

The datasets used and/or analyzed during the current study are available from OE on reasonable request.

Funding

Department of Community Sustainability, College of Agriculture and Natural Resources, Associate Dean Fellowship from Michigan State University, Alliance for Graduate education and the professoriate at Michigan State university for partial funding.

CRediT authorship contribution statement

OE conceived of the study, collected the data, and did all the initial analysis, and wrote the first draft of the paper. JK provided guidance in the data collection and helped to streamline the analysis and the text, and wrote original sections of the text in the final draft. AS helped with the analysis. RR contributed to design of the survey and guidance of study. All authors read and approved the final manuscript.

Declaration of competing interest

The authors declare that they have no competing interests.

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