International Journal of Energy Research
INTERNATIONAL JOURNAL OF ENERGY RESEARCH
Int. J. Energy Res. 2014; **38**:1727–1740
Published online 9 May 2014 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/er.3200

Relative deprivation and energy poverty: when does unequal access to electricity cause dissatisfaction?

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SUMMARY

In the least developed countries, unequal access to infrastructure is a major form of inequality. We examine the conditions under which unequal electricity access causes dissatisfaction. The question is important because grievances could prompt demands for policy change. We argue that feelings of relative deprivation both cause dissatisfaction and create hope for improvement. Empirically, we analyze household survey data from five East African countries. All else constant, households living close to a power line are less satisfied with their lighting solution but also have more hope for improvement. Because household lighting is the most important use for electricity in a poor household, this supports the relative deprivation hypothesis. Households that are reminded of their deprivation by the power line are both less satisfied and believe something can be done to solve the problem. To inform policy, we also show that the proximity of a power line decreases the household's interest in solar home systems as an alternative to grid electrification, whereas valuation for solar lanterns seems to be increasing. Copyright © 2014 John Wiley & Sons, Ltd.

KEY WORDS

infrastructure; electricity; Africa

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Received 24 October 2013; Revised 20 February 2014; Accepted 17 March 2014

1. INTRODUCTION

As countries develop, they invest vast amounts of private and public capital in infrastructure. However, access to such infrastructure is highly uneven [1]. Despite years of investment in power generation, for example, Tanzania's electrification rate remained as low as 14% in the year 2009, while the same rate in Zambia was only 16% ([2]: 45). Even in India, an emerging economy, one-third of the population remains without basic household electricity [3]. While every fifth person in the world is without access to electricity, almost one-third of the rural population suffers from this problem [4]. Not only are some countries victims of energy poverty, but inequality in access to electricity and other modern forms of energy also characterizes them [5].

Uneven access to infrastructure raises the politically and socially central question of how people who are left behind view their relative energy poverty. If infrastructure becomes available for some but not all households, how do those without access view the situation? Does their relative deprivation trigger resentment about the issue, and do they become more pessimistic or optimistic about the possibility of improvements in the situation?

The answer to this question is important for understanding the politics of infrastructure in democratic societies. If people who are left behind hold grievances and demand improvement, this puts pressure on the government to combat energy poverty. Political scientists have argued that democratic accountability induces governments and national leaders to provide public goods to their citizens [6,7], but the state's incentive to provide such goods requires that people demand them [8]. If people who live in relative energy poverty are aware of their situation and demand action by the government, then energy poverty can be alleviated. If the victims of energy poverty remain passive, the government has little incentive to address the problem through new policies. Understanding the effect of unequal access to infrastructure on relative deprivation can help explain and predict changes in a democratic government's incentive to construct infrastructure for the residential sector.

The theory we propose is based on the idea that 'relative deprivation' shapes the thought processes of individuals [9–12]. By relative deprivation, we refer to the case in which an individual has no access to a good or service that others around him or her have, and this unequal access creates frustration and dissatisfaction. If people see that others around them have access to basic necessities and amenities they themselves cannot use, their relative deprivation makes them realize that their situation could be improved. This has two implications. First, people living in relative deprivation should be less satisfied with their situation than other people who also suffer from energy poverty but are not surrounded with households who have adequate access to energy. Second, relative deprivation should make people more optimistic about the possibility of improvement. Because people experiencing relative deprivation see that others around them have access to electricity, they have the reason to believe they also could gain access to the same service.

This article intends to answer the sociopolitical questions raised earlier through an analysis of survey data from five African countries: Ethiopia, Ghana, Kenya, Tanzania, and Zambia. Collected by Lighting Africa [2] in 2008–2009, this is the first publicly available large dataset that specifically focuses on household perceptions of their *lighting situation*. Because one of the most immediate benefit of household electrification is improved lighting,[‡] we can use people's perception of the quality of their domestic lighting as an indication of their satisfaction with access to infrastructure. For each household, the survey data indicate if a power line is visible nearby. This yields an indicator of relative deprivation.

We find that unelectrified households living close to a visible power line are about 4% less likely to be satisfied with their domestic lighting than similar households living in an area where no power lines are visible. We also find that unelectrified households are about 4% more likely to believe that their situation could improve if they can see their neighbors' power lines. While the substantive effects are not very large, the independent variable only captures the visibility of a power line. Some other explanatory variables, such as planned rural areas or better lighting as a priority, have similar magnitudes. Income and household size show a smaller impact. Hence, it appears that a range of factors can explain satisfaction with lighting, not one single dominating one.

These findings are important for scholars and practitioners interested in energy access. Theoretically, the findings contribute to recent studies on 'aspirations' and energy access [13]. We show that relative deprivation increases the importance that households attach to electricity. Parikh *et al*. [13] found that successful slum electrification shifts the focus of the urban poor's aspirations from lower to higher levels of goods and services. We find that relative deprivation both intensifies the perception of inequality and creates hope among unelectrified households for improvements.

Because relative deprivation is an important determinant of dissatisfaction with domestic lighting, the demand for new technologies, such as solar home systems (SHS), could be higher close to a power line than previously thought. While households in such areas hold hopes for a grid connection, at the same time, they are also dissatisfied with their current situation. Therefore, a solar home system could serve as a viable interim solution until they can afford a grid connection and as a secondary solution thereafter [14]. In recent years, the cost of solar power has decreased dramatically and enhanced the competitiveness of solar lighting devices [15]. Moreover, survey studies show that the market for solar lighting is vast in Africa and Asia, where rural electrification rates are low [16,2]. However, additional analysis shows that relative deprivation in terms of electricity actually *reduces* interest in SHS. Households living near to a power line are simply less interested in SHS. In our view, the most plausible explanation for this is that relative deprivation causes them to demand grid electrification, instead of a stopgap measure such as a SHS. At the same time, willingness to pay for solar lamps seems to increase slightly, although the effect is not entirely robust. Contrary to SHS, solar lanterns cannot be viewed as a substitute to grid electrification. As solar lanterns provide transportable but limited lighting, they could even be understood as complementary lighting technologies with respect to SHS or grid-connected fixtures. This means that while the substantively more important SHS market suffers, there is some hope for solar lamps, although the substantive effect in willingness to pay is not very large.

The results also contribute to the sociology and political science of energy access. Progress in rural electrification is heavily dependent on public investment, given the need for transmission and distribution infrastructure [17,18]. Consequently, aggressive investment in rural electrification is a policy that the government must consciously adopt. Our findings suggest that in countries characterized by unequal energy access, governments could face demands for improved policy. The dissatisfaction and frustration that relative deprivation creates are fuel for political demands for decisive measures against energy poverty. In the state of Bihar in India, for example, acute power shortages caused unrest and rioting in the industrial town of Begusarai in May 2012.[§] To be sure, relative deprivation will only influence public policy if the government itself has political incentives to respond to changes in mass opinion. This, in turn, depends on the quality and maturity of a country's political institutions [19]. Our findings call for more research on the institutional aspects of energy poverty, with a particular focus on variation in the incentives of governments to respond to voter demands for improvement.

2. RELATIVE DEPRIVATION AND PERCEIVED QUALITY OF ENERGY SERVICES

By relative deprivation, we refer to the possibility that 'comparisons to other people, groups, or even themselves

[‡]Mobile charging has become an equally important part of energy access in some developing countries.

[§]See http://www.rediff.com/money/report/bihars-industrial-town-to-protest-against-power-shortage/20120525.htm. Accessed February 7, 2014.

at different points in time lead people to believe that they do not have what they deserve, they will be angry and resentful' ([12]: 203). The term was originally proposed by Stouffer *et al*. [20] and has since become a staple of social psychology. In political science, relative deprivation has been proposed to be a possible source of conflict [11]. In general, the empirical evidence for the effects of relative deprivation on behavior suggests the need for nuanced and contextual models [12]. Here, we achieve this goal by squarely formulating our theory in terms of energy poverty.

In the context of energy poverty, relative deprivation refers to the possibility that people consider their access to energy to be less than what they deserve. Because our focus is on relative deprivation with respect to an individual's environment, we focus here on horizontal comparisons with other people. In most industrialized countries, energy poverty is largely nonexistent, as even the poorest households have access to electricity and heating fuel. In developing countries, however, access to basic energy is highly uneven [21]. In addition to the positive effect of household income on access to energy, for example, it is notable that rural households are generally more deprived than urban households [22].

2.1. Access to infrastructure and relative deprivation

According to the definition of relative deprivation, grievances and anger should emerge when people feel they are lacking something they deserve. We argue that the presence of inaccessible energy infrastructure provokes such feelings. Given the data we use, we formulate this argument in terms of household electrification. To understand the argument, consider a household that does not have access to the electricity grid. Such a household can either find itself in a situation in which electricity is not at all available in its environs or, alternatively, see that electricity is made available to others, but not to this household, because there is a power line nearby.

The key analytical difference between the two situations, near or far from a power line, is the following:

- If there is no power line nearby, the unelectrified household does not experience relative deprivation. After all, other households in the area also do not have access to electricity.
- If a power line is found nearby, the unelectrified household experiences relative deprivation. After all, the presence of the power line shows that some other households can access electricity.

The power line is a visible sign to the members of the household that it is not gaining access to electricity, while other consumers in the area are. A household that is far removed from a power line is not reminded about unequal access to electricity every day, whereas a household that does live in the proximity of a power line sees the unequal situation in everyday life.

For poor households in developing countries, lighting is the first and most fundamental use of electricity. Because lighting does not require large loads of power, it is affordable even to a poor household that has few electric assets [23]. Unelectrified households rely on expensive and ineffective substitutes, such as kerosene [24]. These substitutes do not offer the same quality of lighting that an electric light would, and they are also a health hazard [25,24]. Therefore, we can test our relative deprivation hypothesis by examining the household's satisfaction with domestic lighting. If an unelectrified household experiences relative deprivation because of the presence of a power line, it should be less satisfied with the substitute to electricity that it is using for domestic lighting. Because lighting is the most important use of electrification, unelectrified households who experience relative deprivation should be more frustrated about their lighting situation.

Hypothesis 1. Unelectrified households are less satisfied with their domestic lighting if there is a power line nearby.

While our data cannot speak to the possibility that relative deprivation reflects ethnic or religious cleavages, this theoretical possibility is worth a brief discussion. According to some studies, such as the Appelgryn and Bornman [26] study of the racial attitudes of Blacks and Whites in South Africa, relative deprivation strengthens negative perceptions of other ethnicities. If this logic holds, then relative deprivation would occur in areas with high levels of ethnic fractionalization. Similarly, if religious cleavages were to prove decisive, then we would expect high levels of religious fractionalization to predict perceptions of relative deprivation. A household that perceives households of a different religiosity or ethnicity to have access to electricity would be particularly prone to experiencing feelings of relative deprivation.

2.2. Aspirations and optimism about improved access

What about other testable implications of the theory? Reaching beyond our basic hypothesis on relative deprivation, we argue that the relative deprivation that the power line induces also has a positive side. Following Parikh *et al*. [13], we consider electricity as one of the 'aspirations' that poor households in developing countries can have. A poor household lacks access to many basic goods and services, such as clean water and convenient cooking fuels. Improved access to these is an aspiration that the household hopes to realize in the future.

For every such aspiration, a poor household formulates a subjective probability on the possibility that the situation could be improved in the near future. This subjective probability captures their belief in possible improvements. We argue that unelectrified households experiencing relative deprivation due to the presence of a power line can be expected to be more optimistic about improving their situation. For a household experiencing relative deprivation, the realization that other people have access to electricity through the power line means that this household expects to be able to connect to the power line in the future with some nonzero probability.

In contrast, a household that is far removed from a power line has fewer reasons to be optimistic. Because this household is not reminded of the availability of electricity to other households, it may believe that electricity is simply not going to be available for consumption in the area. For example, such a household could believe that the construction of a distribution line for the area would be too expensive, and so the government would not do it. Conversely, a household living next to a power line can only ascribe the lack of electricity to the lack of a household connection.

Compared with a household that is far removed from a power line, the first household's prospects of securing access to the electricity grid should be much better. It must still deal with the problem of obtaining a household connection, which is very expensive in most developing countries [27], but at the very least, it need not wait until an actual power line is built. Therefore, relative deprivation may also instill optimism among unelectrified households about improvements in their energy access situation. For reasons discussed earlier, this hypothesis can also be formulated in terms of domestic lighting.

Hypothesis 2. Unelectrified households are more optimistic about improving their domestic lighting if there is a power line nearby.

3. RESEARCH DESIGN

To test the aforementioned hypotheses, we use survey data on household satisfaction with domestic lighting and belief in the possibility of improvement. We examine the effect of the nearby presence of a power line on these variables.

3.1. Data

The data for the project were collected by Lighting Africa [2] in the years 2008–2009 for Ghana, Kenya, Tanzania, Zambia, and Ethiopia. The questionnaire covered a wide array of topics, and the key variables used for our study are described in the online Appendix.

Of the five countries, all but Ghana have very low national levels of electrification. According to the International Energy Agency, the East African countries have the following household electrification rates in 2011: Kenya (0.18), Tanzania (0.15), Zambia (0.19), and Ethiopia (0.23) [4]. In contrast, Ghana's electrification rate was as high as 0.61. In the East African countries, electricity is often not even available in urban areas, let alone the countryside, while Ghana's achievements in rural electrification have been impressive. As Eberhard *et al*. [28] show, most countries in Sub-Saharan Africa have highly inefficient power sectors and have neglected investment in electrification for decades. The lack of electrification in these areas does not depend so much on explicit political discrimination but rather on low levels of investment in public infrastructure in general. In Ghana, the government has successfully generated hydroelectric power since 1965, and progress in improving electricity access has been impressive since the formulation of the national electrification scheme in 1989 and 1990 [29]. However, rural areas continue to suffer from low electrification levels because of the high cost of electrification.

In each country, the survey company conducted 1000 interviews with consumers, from both rural and urban areas. Each country was divided into key geographic regions.[¶] In each region, a random starting point was chosen and interviewers followed a random route from this point until identifying a dwelling (off-grid or on-grid). Having completed the interview, the enumerators were requested to skip five dwellings before starting the random walk again. There are in total 527 random routes or enumeration areas. The enumerators were instructed to ensure that they interview households according to the desired distribution of grid and off-grid households, which was set to a maximum of 10% grid-connected households. As a result, of the total 5000 observations, 4500 are households without access to electricity. They will form our sample. In rural areas, this meant that many enumeration areas had only unelectrified households. In planned urban areas, every fourth household was electrified. Also in this regard, the sample matches the reality in these countries quite well, with the exception of Ghana, where electrification rates are unusually high.

3.2. Model

To test the two hypotheses, we estimate linear probability models based on ordinary least squares. They are of the following form:

$$Y_i = \alpha + \beta \text{Power Line}_i + \gamma \mathbf{X}_i + \delta + \epsilon_i, \qquad (1)$$

where Y_i is either satisfaction with lighting or belief in the possibility of improvement in household i. Next, β is the coefficient for the presence of the power line. We expect it to be negative for the first dependent variable and positive for the second. Vector $\mathbf{X}_i$ captures relevant covariates for household i, δ is a set of 35 region fixed effects, and ϵ_i is the error term. Throughout, we estimate robust standard errors clustered by the enumeration area. We present linear probability models here because they are easy to

[¶]The different geographic areas are indicated here. Ethiopia: Addis Ababa, Oromiya, Tigray, SNNP region, and Amhara. Ghana: Ashanti, Greater Accra, and Northern Ghana. Zambia: Lusaka, Central Zambia, Copper Belt, Eastern Zambia, Northern Zambia, and Southern Zambia. Kenya: Nairobi, Eastern Kenya, Coast, North-Eastern Kenya, Western Kenya, Nyanza, Central Kenya, and Rift Valley. Tanzania: Dar es Salaam, Dodoma, Kilimanjaro, Morogoro, Mbeya, Tabora, Shinyanga, Tanga, Arusha, and Iringa.

interpret. In the Appendix, we replicate the models with nonlinear specifications using probit regressions. We also use coarsened exact matching as an alternative method to estimate the effect. Results are presented in the Appendix.

3.3. Dependent variables

We use the variable 'household lighting adequacy' as our first dependent variable. This variable is a dummy that equals 1 if the respondent said that the household was well lit for the purposes for which light is required, and equals 0 if he or she said it was poorly lit. A poorly lit household is a key source of dissatisfaction with domestic lighting. Hence, we use this variable as a proxy for satisfaction with domestic lighting. This allows us to directly test Hypothesis 1, given that lighting is the main use of electricity in a poor household. Figure 1 describes the distribution of the variable for each individual country. Most households consider their lighting to be poor. For example, in Kenya, 185 respondents said it was well lit and 720 said it was badly lit. In Table I, summary statistics are presented for the key variables. We note that 'household lighting adequacy' has a mean of 0.28, which means that 1256 respondents out of 4528 said that their household was well lit. This distribution offers enough variation in the data to test our hypothesis.

As a second dependent variable, we used the variable 'Believe light could improve'. This variable equals 1 if the respondent answered positively to the question, 'Could the light in this household be improved?' and 0 otherwise. In other words, if the answer is 'yes', the respondent believes that the lighting situation of the household can be improved. This would imply that the respondent understands that the current lighting is not the best and that there is some hope for improvement. A positive answer to this question reveals optimism about obtaining better lighting. Once aware of their relative deprivation, individuals might develop a feeling of frustration if they observe improvements in other people's situation and experience none in their own. Although aware that some technologies could improve their lighting, they are probably pessimistic about obtaining them and answer that they do not believe their lighting could improve. Hence, we use the variable 'Believe light could improve' as a proxy for optimism about improvement in lighting, allowing us to test Hypothesis 2.

One possible concern about this approach is that the perceived quality of lighting and scope for improvement are negatively correlated. In our data, the negative correlation is indeed strong, $r = -0.31$ (see correlation matrix in the online Appendix). In a robustness check, we check the effect of power line visibility on optimism while controlling for the quality of lighting. This approach is not ideal because of the endogeneity between the two dependent variables, but it is reassuring to see that this control does not change our result. The negative correlation does not seem to be a problem for our estimation.

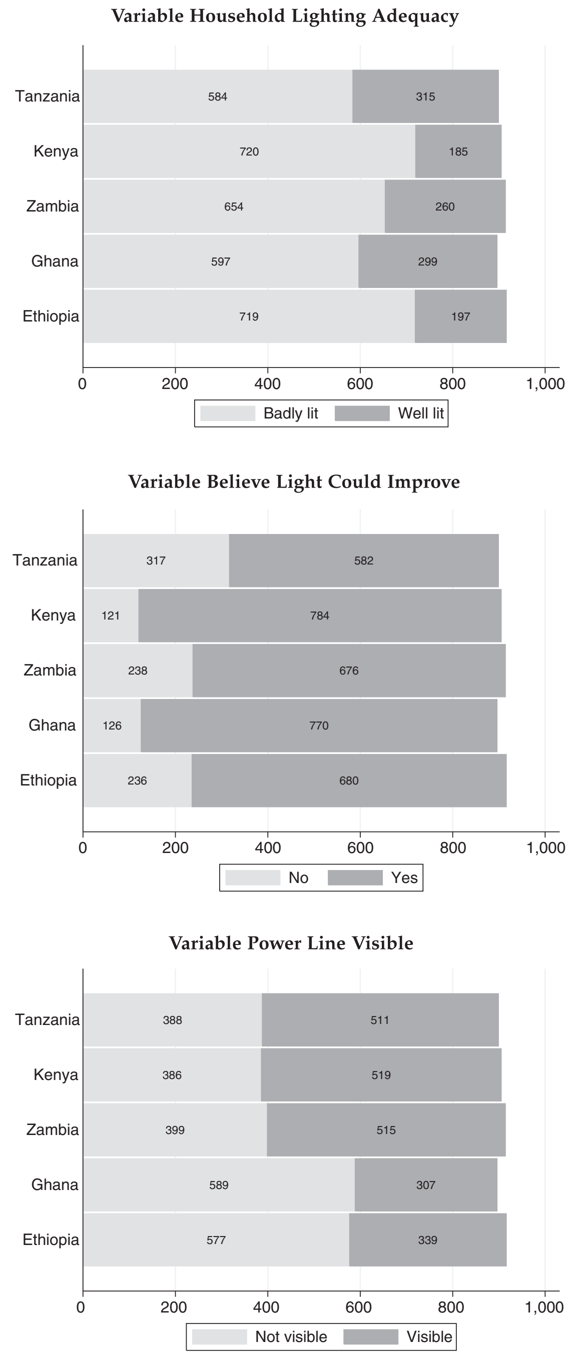

Figure 1. Distribution of key variables: counts per country.

3.4. Main explanatory variable

Our main explanatory variable, 'power line visible,' indicates whether or not the household can see a power line from home. This variable equals 1 if the interviewer observed that there was a visible power line nearby the dwelling and 0 otherwise. While all households in the sample are unelectrified, some of them live in the proximity of

Table I. Summary statistics.

	Count	Mean	SD	Min	Max
Power grid connection	4530	0.00	0.00	0.00	0.00
Power line visible	4530	0.48	0.50	0.00	1.00
Household lighting adequacy	4530	0.28	0.45	0.00	1.00
Believe light could improve	4530	0.77	0.42	0.00	1.00
Current lighting has negative effects on vision	4530	0.33	0.47	0.00	1.00
Better lighting is a priority	4530	0.35	0.48	0.00	1.00
Income category	4530	6.69	5.95	0.00	21.00
Household size	4530	4.40	1.65	1.00	7.00
Male	4530	0.59	0.49	0.00	1.00
Age category	4504	2.92	1.08	1.00	5.00
Education level	4530	2.25	1.47	0.00	8.00
Telephone	4174	0.31	0.46	0.00	1.00
Homeowner	4530	0.81	0.39	0.00	1.00
Worry about health effects of kerosene	4530	0.18	0.39	0.00	1.00
Worry about environment effects of kerosene	4530	0.11	0.31	0.00	1.00
Time when getting dark	4530	4.36	1.12	1.00	7.00
Unplanned rural area	4530	0.60	0.49	0.00	1.00
Planned rural area	4530	0.10	0.30	0.00	1.00
Unplanned urban area	4530	0.22	0.41	0.00	1.00
Planned urban area	4530	0.08	0.27	0.00	1.00
Novelty perception of SHS	4530	4.12	1.00	1.00	5.00
Interested in SHS	4530	4.61	0.64	1.00	5.00

SHS, solar home systems; SD, standard deviation.

a power line. Of the 2191 households with a visible power line, 1474 report it being on the same street or road.[‖] These lines might be simple distribution lines or larger transmission lines, but regardless of the type, a majority of respondents perceive the grid as *close by*.

Figure 1 describes the distribution of the variable for each individual country for off-grid households. In our samples from Tanzania, Kenya, and Zambia, there are more dwellings for which a power line is visible nearby than dwellings without a power line visible nearby. The samples for Ghana and Ethiopia present the opposite feature. Because electrification rates in these two countries are high, households that are still unconnected to the grid might be particularly remote. Hence, a majority of these would not have a power line in sight in their surroundings. In all cases, both outcomes are significantly represented. The mean for the entire sample is 0.48. In addition, Table A3 in the Supplementary Appendix displays summary statistics contingent on whether a power line is visible or not. The samples from the two groups have similar characteristics in terms of household size, income category, and age.

Material presented in the online Appendix provides further information about the distribution of the variable 'power line visible' in each enumeration area. Indeed, a possibility would be that no variation exists within each cluster, that is, in each enumeration area, either a power line is visible for all of the households or for none of them. Histograms displayed in the Appendix show that the proportion of households with a visible power line in each cluster varies between 0% and 100%.

3.5. Control variables

Failing to control for the other factors impacting our dependent variables would lead to omitted variable bias, and therefore, to biased coefficients. Controlling for additional explanatory variables allows to reduce their confounding effect. Because we expect the two dependent variables to be determined by similar factors, we include the same set of control variables in both regression equations. For maximal robustness, we vary the set of control variables across the estimated regression models. Some models have more and others have fewer controls. In particular, we pay attention to excluding potentially endogenous regressors from some of the models. One model also includes no control variables at all.

As control variables, we include individual characteristics such as household head's gender, age, and education level because it is possible that these factors affect individual's satisfaction with lighting and the perception of possible improvement. In particular, the existence of differences in gender roles might cause men and women to experience the quality of light differently. In addition, younger people might display more optimism about improving their living conditions, and less satisfaction about their current situation, whereas older people could possibly be more skeptical

[‖]This information was derived from one of the questions during the interview asking how far away the nearest power line was. Further details appear in the Appendix.

DOI: 10.1002/er

of seeing improvement in their access to infrastructure. Also, possibly, the more educated the respondent, the more aware of existing technologies and other life improving opportunities. This, in turn, could yield a higher level of optimism and lower levels of satisfaction about the current status of the household's lighting conditions.

On top of individual characteristics, household factors might also affect significantly the two outcome variables. In particular, the household income could be a critical control variable because richer households can afford lighting technologies that offer better intensity or greater efficiency. As a result, the level of satisfaction with their current situation is likely to be higher than poorer households. However, it is also possible that, even though they are rich enough to afford grid connection, they are still not offered this possibility. In that case, richer households might display lower satisfaction level. Poor people might also think that any improvement is unlikely and might be just satisfied with their current situation. In addition, richer households might not display any particular belief that their situation could improve if they believe they are well endowed already. The variable 'income category' has numerous missing observations, causing significant attrition of the sample when added to the analysis. To strengthen the estimation, we created a 'missing income' dummy, which equals 1 when an observation for the income of the household is missing and equals 0 if not. This allows missing observations to be taken into account without introducing bias.

We also include a variable for the size of the household, because the greater the amount of people living in the household, the more numerous and diverse the activities performed at night. There is no correlation between household size and the categorical income variable, however need for light would be made more acute by intense household chores and more children with homework for school to complete. For these reasons, it is likely that larger households are less satisfied about their current lighting. We also include the time at which it gets dark, because it determines how long the household requires light to continue its activities. Although Dawn and dusk times do not vary much across these countries, there is some seasonal variation.

The questionnaire also asked each respondent what they would like to change about their dwelling in priority. We have created a dummy variable that equals 1 if the household responded that their priority would be better lighting and 0 otherwise. This variable is included as a control because it is likely to be significantly correlated with both dependent variables. An off-grid household that is mostly using kerosene lamps and says that better lighting is their priority number one should be less satisfied with their lighting conditions and believe that improvement is possible.

Home ownership is also likely to affect the perception of possibility for improvement, because ownership might induce a greater feeling of empowerment with respect to making decisions about the dwelling. People not owning their unit might have to coordinate their actions with their landlord for decisions such as connecting the house to the electrical grid. As a result, home ownership might be positively correlated with the perception of possibility for improvement.

Similarly, telephone ownership is likely to affect the dependent variables. Telephone users might have a more developed social network, through which they become aware of new opportunities. Consequently, they might be more dissatisfied with their current lighting and be more hopeful about potential improvements.

We also include control variables for the types of area in which the dwelling is located (planned urban, unplanned urban, planned rural, and unplanned rural). Living close to a shopping center in a planned rural area, as opposed to living in a remote unplanned rural area, is likely to affect one's perception of possibility for improvement, as well as the level of satisfaction with lighting. In particular, the low spread of better technologies in rural unplanned areas makes people little aware of existing opportunities [30]. As a result, households in rural unplanned areas are likely to be more satisfied with their conditions and not to believe it could improve. We also use variables that indicate whether or not the respondent worries about the health and environmental effects of kerosene, because this worry could drive stronger interest in safer and cleaner technologies.

Summary statistics for these variables are displayed in Table I. More details about these variables can be found in the online Appendix. There, we also present statistics by country. This allows us to compare the mean values of the different variables for each country and identify whether any peculiarity exists in some country. Most of the variables have comparable means across countries. We note, however, that Ethiopia displays values further from the mean of other countries.

Concerning omitted variables, the survey misses a few factors that could influence lighting satisfaction and belief in improvements. One is general beliefs concerning the government's competence and the country's trajectory. Another is perception of the quality of lighting in surrounding areas and awareness of progress in rural electrification. From a more psychological perspective, general measures of happiness and optimism would also have been useful.

4. FINDINGS

We begin by reporting the main results on the two dependent variables. Then, we summarize an array of robustness checks. Finally, we examine if relative deprivation also influences a household's stated willingness to pay for solar power as a substitute for power line.

4.1. Main results

The estimation of the model of a household's perceived adequacy of lighting is reported in Table II. Model (1) does not contain any control variables, while models (2) and (3) include different sets of the controls mentioned earlier. All models use regional fixed effects for 35 geographic areas. This allows us to control for unobserved regional factors that could correlate with the independent variables. All models use standard errors clustered at the enumeration area level.

In all three models for household's perception of lighting adequacy, we observe strong negative correlations between lighting adequacy and whether or not a power line is visible nearby. Model (1) provides an estimate of −0.042 significant at the 5% level, and the estimate barely changes when controls are added in models (2) and (3). People who have a power line nearby their house are about 4% less likely to describe their household as 'well lit'. This result provides empirical evidence for Hypothesis 1. This estimate might seem fairly small at first sight. However, considering the nature of the independent variable, merely the fact that a power line is visible nearby, 4% might appear surprising. In addition, it is of the same order of magnitude compared with the estimates for some of the control variables.

Table II. Ordinary least squares results with dependent variable: household lighting adequacy.

	(1)	(2)	(3)
Power line visible	−0.042**	−0.040**	−0.040**
	(0.019)	(0.019)	(0.019)
Household size		−0.009*	−0.009*
		(0.005)	(0.005)
Male		−0.027	−0.025
		(0.016)	(0.017)
Age category		0.004	0.004
		(0.008)	(0.008)
Education level		0.001	0.001
		(0.007)	(0.007)
Telephone		0.015	0.020
		(0.021)	(0.020)
Homeowner		0.031	0.034
		(0.023)	(0.023)
Time when getting dark		0.001	0.002
		(0.010)	(0.010)
Income category		0.006***	0.005***
		(0.002)	(0.002)
Missing income dummy		0.034	0.030
		(0.027)	(0.026)
Planned rural area		−0.065**	−0.062**
		(0.028)	(0.028)
Planned urban area		0.013	0.019
		(0.044)	(0.044)
Unplanned urban area		−0.019	−0.015
		(0.027)	(0.027)
Worry about health effects of kerosene			−0.045**
			(0.022)
Worry about environment effects of kerosene			−0.018
			(0.030)
Better lighting is a priority			−0.038**
			(0.018)
Region FE	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes
R-squared	0.082	0.082	0.085
Observations	4530	4156	4156

Standard errors are in parentheses.
Dependent variable: household lighting adequacy.
FE, fixed effects; SE, standard error.
*$p < 0.10$.
**$p < 0.05$.
***$p < 0.01$.

Among the controls that display a significant negative correlation with the dependent variable are the indicators for whether the household lived in planned rural areas (6.5%), worried about the health effects of kerosene (4.5%), and considered better lighting as a priority (3.8%). All these are as expected, strengthening our confidence in the models. We also observe a strong positive correlation of the dependent variable with the size of the household (0.9%) and the income category (0.6%). Besides, regional fixed effects can have very large effects (up to 50%). It seems that there is no dominant factor impacting the perception of lighting adequacy, but instead, a range of variables are significantly correlated.

Table III presents the results of the estimation for a household's perception of the possibility of improvement. Similar to the previous estimation, model (1) does not contain any control variables, while models (2), (3), and (4) include different sets of controls. All models use regional fixed effects, and standard errors are clustered at the enumeration area.

In all four models, we observe strong positive correlations between lighting adequacy and whether or not a power line is visible nearby. Model (1) provides an estimate of 0.043 significant at the 5% level. People who have a power line nearby their house are about 4% more likely to believe that their current situation can improve. This result provides empirical evidence for Hypothesis 2. When adding the control variables in models (2) and (3), the estimate decreases to 0.035 and 0.037, respectively, and is different from zero at the 10% significance level. Model (4) will be discussed in the robustness checks section.

Among the controls that display a significant positive correlation with the dependent variable are the size of the household, the dummy for home ownership, the dummies for whether the respondent worried about health and environmental effects of kerosene, the time at which it gets dark, if better lighting is a priority, and if the household lived in planned rural or in unplanned urban areas. All these are as expected, strengthening our confidence in the models. For example, full ownership of the home can encourage people in improving their dwelling, while households living in more active areas are more aware of the existence of improvement opportunities. Strong negative correlations are observed for the missing income category, indicating that households that did not want to report their income are less optimistic about improving their situation.

4.2. Another dependent variable: lighting and vision

We have applied the same econometric strategy to the variable 'current lighting has negative effects on vision'.

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DOI: 10.1002/er

Table III. Ordinary least squares results with dependent variable: believe light could be improved.

	(1)	(2)	(3)
Power line visible	0.043**	0.037*	0.035*
	(0.019)	(0.019)	(0.019)
Household size		0.013***	0.013***
		(0.004)	(0.004)
Male		0.015	0.013
		(0.015)	(0.015)
Age category		−0.004	−0.004
		(0.007)	(0.007)
Education level		0.001	0.002
		(0.006)	(0.006)
Telephone		0.033*	0.026
		(0.018)	(0.017)
Homeowner		0.050**	0.046**
		(0.020)	(0.020)
Time when getting dark		0.015*	0.014*
		(0.008)	(0.008)
Income category		−0.001	−0.001
		(0.001)	(0.001)
Missing income dummy		−0.086***	−0.080***
		(0.027)	(0.027)
Planned rural area		0.046*	0.042*
		(0.024)	(0.024)
Planned urban area		0.059	0.052
		(0.038)	(0.038)
Unplanned urban area		0.078***	0.073***
		(0.021)	(0.022)
Worry about health			0.049**
effects of kerosene			(0.021)
Worry about environment			0.051**
effects of kerosene			(0.022)
Better lighting is a priority			0.043***
			(0.015)
Region FE	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes
R-squared	0.128	0.150	0.156
Observations	4530	4156	4156

Standard errors are in parentheses.
Dependent variable: believe light could improve.
FE, fixed effects; SE, standard error.
*$p < 0.10$.
**$p < 0.05$.
***$p < 0.01$.

Respondents for which this variable equals 1 reported thinking that their current lighting affected their vision in a negative way. Positive correlation of this variable with 'power line visible' would indicate that respondents aware of their relative deprivation are also more sensitive to some of the drawbacks of their current technology. In particular, respondents with a visible power line nearby might be more aware that grid electricity provides better lighting. Detailed results are displayed in the online Appendix. Households are 4.6% more likely to think that their current lighting has negative effects on their vision if they live with a visible power line nearby.

4.3. Probit estimation

Because our dependent variables are dummies, a probit estimation strategy must be considered. Results are reported in the Appendix. Similar significance was obtained in both the linear model and probit model at the 5% significance level. The marginal effect coefficients are also comparable with the ordinary least squares (OLS) coefficients. The marginal effect of 'power line visible' on the probability to rate the current lighting as 'well lit' is equal to −0.043 for the model with the control variables, while the same model in the linear estimation yielded a coefficient of −0.040. Similarly, for the perception of possibility of improvement, significance levels are identical, and marginal effects for the linear and probit model are, respectively, 0.035 and 0.037.

4.4. Robustness tests

Because perception of light quality is negatively correlated with 'Believe light could improve', we check the effect of power line visibility on optimism while controlling for light quality perception. Table IV displays the previous results along with the inclusion of 'household lighting adequacy' as a control. This setting is not ideal because of correlations between the explanatory variables. Hence, although we lose significance, we attribute more importance to the fact that coefficients go in the same direction.

To further check the robustness of the results, regressions were performed for each country separately, with and without the set of controls. Results are reported in the Appendix. The sample size is greatly reduced, and statistical significance is no longer obtained. However, all estimates are going in the same direction when compared with total sample.

5. IMPLICATIONS FOR SOLAR POWER ADOPTION

The data also allow us to examine the possibility that relative deprivation increases demand for alternatives to grid extension. During the interview, respondents were explained how SHS work and asked if they thought the concept was novel and if they would be interested in having it for their household. The explanation of SHS given by the enumerators did not mention any prices, but specified that households would be able to run between one and four light bulbs with such a system.[**] These variables allow us to investigate if the perception of relative deprivation affects perceptions of

[**]The explanation given to the respondents was as follows. The concept works by placing a solar panel on the roof of your house. In the house, you will have a transformer, which stores the sun energy in a rechargeable battery. From the transformer, you will be able to run a number of lights (between one and four) into different areas of the house (for example, different rooms) and switch these lights on and off individually and as you need them.

Table IV. Robustness check for ordinary least squares results with dependent variable: believe light could be improved.

	(1)	(2)	(3)	(4)
Power line visible	0.043**	0.037*	0.035*	0.025
	(0.019)	(0.019)	(0.019)	(0.017)
Household size		0.013***	0.013***	0.011***
		(0.004)	(0.004)	(0.004)
Male		0.015	0.013	0.006
		(0.015)	(0.015)	(0.014)
Age category		−0.004	−0.004	−0.003
		(0.007)	(0.007)	(0.007)
Education level		0.001	0.002	0.002
		(0.006)	(0.006)	(0.006)
Telephone		0.033*	0.026	0.031*
		(0.018)	(0.017)	(0.017)
Homeowner		0.050**	0.046**	0.054***
		(0.020)	(0.020)	(0.020)
Time when getting dark		0.015*	0.014*	0.015**
		(0.008)	(0.008)	(0.007)
Income category		−0.001	−0.001	0.000
		(0.001)	(0.001)	(0.001)
Missing income dummy		−0.086***	−0.080***	−0.072***
		(0.027)	(0.027)	(0.026)
Planned rural area		0.046*	0.042*	0.026
		(0.024)	(0.024)	(0.023)
Planned urban area		0.059	0.052	0.056
		(0.038)	(0.038)	(0.037)
Unplanned urban area		0.078***	0.073***	0.069***
		(0.021)	(0.022)	(0.020)
Worry about health effects of kerosene			0.049**	0.037*
			(0.021)	(0.019)
Worry about environment effects of kerosene			0.051**	0.047**
			(0.022)	(0.021)
Better lighting is a priority			0.043***	0.033**
			(0.015)	(0.015)
Household lighting adequacy				−0.253***
				(0.022)
Region FE	Yes	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes	Yes
R-squared	0.128	0.150	0.156	0.224
Observations	4530	4156	4156	4156

Lighting adequacy is included in model 4 for the robustness check.
Standard errors are in parentheses.
Dependent variable: believe light could improve.
FE, fixed effects; SE, standard error.
*$p < 0.10$.
**$p < 0.05$.
***$p < 0.01$.

SHS. This analysis is useful from a policy perspective, given that our theory does not provide clear expectations on this issue. On the one hand, relative deprivation could make people turn to alternatives because of the need to address their highly salient problem. On the other hand, if people consider solar-powered electricity as a technology inferior to grid-provided electricity, relative deprivation might make people refuse such alternatives. Given this indeterminacy, we do not attempt to formulate *a priori* hypotheses. However, the issue is worth investigating because it could have important implications for the adoption of solar technologies in countries under consideration. For example, if relative deprivation increases demand for home systems, then areas with power lines should be the priority for the deployment of such products.

Ordinary least squares results are reported in Table V for ‘novelty’. We observe negative correlations between SHS perceived as novel and proximity to a visible power line. In all three models, the coefficients are significant at the 5% level with clustered standard errors. Table VI shows

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DOI: 10.1002/er

the results for the variable 'interest'. We again see that the visibility of a power line reduces interest in SHS, although the statistical robustness of this finding is questionable. The estimated coefficient is negative for all models but significant at the 10% level in only two out of three models.

These results are noteworthy for their magnitude. Households with a visible power line nearby are about 10% less likely to think of SHS is a novel idea and about 5% less likely to be interested in obtaining it. As we saw with the result on lighting satisfaction, living in an area where a power line is visible makes access to quality lighting a more salient problem. However, results on novelty perception of SHS indicate that people are less likely to turn to such an alternative technology. One explanation might be that they now believe to have a fundamental right to grid electricity and perceive any other technology as second-class improvements.

The survey also included questions about the price of different solar lamps. Respondents were asked to give the prices at which they thought a product was too expensive, expensive, and cheap. These variables allow us to investigate if relative deprivation can affect households' perception of solar lamps affordability by examining if having a visible power line nearby correlates significantly with the prices reported.

Table V. Ordinary least squares results with dependent variable: novelty perception of solar home systems.

	(1)	(2)	(3)
Power line visible	−0.103**	−0.105**	−0.106**
	(0.043)	(0.045)	(0.045)
Household size		−0.002	−0.002
		(0.011)	(0.011)
Male		0.066**	0.064*
		(0.033)	(0.033)
Age category		−0.001	−0.001
		(0.018)	(0.018)
Education level		−0.064***	−0.063***
		(0.014)	(0.014)
Telephone		−0.072	−0.079*
		(0.047)	(0.047)
Homeowner		−0.062	−0.068
		(0.050)	(0.050)
Time when getting dark		0.038*	0.037*
		(0.020)	(0.020)
Income category		0.005	0.005
		(0.004)	(0.004)
Missing income dummy		0.019	0.026
		(0.063)	(0.063)
Planned rural area		0.051	0.047
		(0.065)	(0.065)
Planned urban area		−0.052	−0.059
		(0.126)	(0.125)
Unplanned urban area		0.190***	0.183***
		(0.058)	(0.058)
Worry about health			0.032
effects of kerosene			(0.057)
Worry about environment			0.074
effects of kerosene			(0.068)
Better lighting is a priority			0.051
			(0.041)
Region FE	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes
R-squared	0.136	0.155	0.156
Observations	4530	4156	4156

Standard errors are in parentheses.
Dependent variable: novelty.
FE, fixed effects; SE, standard error.
$^{*}p < 0.10$.
$^{**}p < 0.05$.
$^{***}p < 0.01$.

Table VI. Ordinary least squares results with dependent variable: interest in solar home systems.

	(1)	(2)	(3)
Power line visible	−0.040	−0.052*	−0.053*
	(0.029)	(0.030)	(0.030)
Household size		0.014*	0.015*
		(0.008)	(0.008)
Male		0.046**	0.047**
		(0.022)	(0.022)
Age category		0.014	0.014
		(0.012)	(0.012)
Education level		−0.014	−0.014
		(0.009)	(0.009)
Telephone		0.017	0.014
		(0.028)	(0.028)
Homeowner		−0.021	−0.024
		(0.034)	(0.034)
Time when getting dark		0.024**	0.024*
		(0.012)	(0.012)
Income category		0.000	0.000
		(0.002)	(0.002)
Missing income dummy		0.011	0.015
		(0.042)	(0.042)
Planned rural area		0.029	0.027
		(0.044)	(0.044)
Planned urban area		0.071	0.068
		(0.063)	(0.063)
Unplanned urban area		0.106***	0.101***
		(0.032)	(0.033)
Worry about health			−0.017
effects of kerosene			(0.034)
Worry about environment			0.064
effects of kerosene			(0.044)
Better lighting is a priority			0.022
			(0.025)
Region FE	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes
R-squared	0.032	0.046	0.047
Observations	4530	4156	4156

Standard errors are in parentheses.
Dependent variable: interested.
FE, fixed effects; SE, standard error.
$^{*}p < 0.10$.
$^{**}p < 0.05$.
$^{***}p < 0.01$.

Relative deprivation might make households' need for better technologies more pressing, making solar lamps an attractive improvement to their situation. The perceived value of solar lamps would increase, and, as a result, people might be willing to pay higher prices for such products. In that case, we should expect the price variables to be positively correlated with having a visible power line nearby.

Table VII reports the OLS results on perception of lamp prices being too expensive. This is the respondent's answer to the question 'At which price would you consider the price of a rechargeable lantern to be too expensive so that you would not consider buying it?'. A positive coefficient indicates a higher willingness to pay. More detailed description of this variable can be found in the Appendix, as well as OLS results for other price variables. We find some indication that lanterns and torches are more valued by households with a visible power line nearby. Most price variables for lanterns and torches correlate positively with 'power line visible,' although the effect is not always significant for every type of lamp and when some control variables are added. Task lights, on the other hand, provide much less evidence. This might be because households tend not to like

Table VII. Ordinary least squares results on price of various types of solar lamp.

OLS results on perception of lamp price being too expensive

	(1) Lantern	(2) Lantern	(3) Torch	(4) Torch	(5) Task light	(6) Task light
Power line visible	0.086**	0.056	0.087***	0.081**	0.039	−0.003
	(0.034)	(0.036)	(0.033)	(0.033)	(0.034)	(0.034)
Household size		0.031***		0.005		0.009
		(0.008)		(0.008)		(0.008)
Male		−0.016		−0.038		−0.032
		(0.025)		(0.025)		(0.024)
Age category		0.002		0.006		0.010
		(0.012)		(0.012)		(0.012)
Education level		0.048***		0.019*		0.042***
		(0.010)		(0.010)		(0.009)
Telephone		0.122***		0.084***		0.086***
		(0.030)		(0.031)		(0.031)
Homeowner		0.010		0.048		−0.033
		(0.037)		(0.036)		(0.035)
Worry about health effects of kerosene		0.026		0.039		0.092***
		(0.037)		(0.035)		(0.035)
Worry about environment effects of kerosene		−0.132***		−0.023		−0.128***
		(0.050)		(0.050)		(0.049)
Time when getting dark		−0.021		−0.025		−0.018
		(0.016)		(0.016)		(0.015)
Income category		−0.004		−0.004		−0.003
		(0.003)		(0.003)		(0.003)
Missing income dummy		−0.061		−0.133***		−0.082
		(0.051)		(0.047)		(0.051)
Better lighting is a priority		−0.062*		−0.050*		−0.052
		(0.033)		(0.029)		(0.032)
Planned rural area		−0.004		−0.044		−0.011
		(0.050)		(0.042)		(0.046)
Planned urban area		0.145*		−0.012		0.086
		(0.079)		(0.080)		(0.072)
Unplanned urban area		0.055		0.086**		0.101**
		(0.044)		(0.039)		(0.043)
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
Clustered SE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.261	0.289	0.123	0.140	0.197	0.228
Observations	4528	4154	4527	4153	4528	4154

Standard errors are in parentheses.
FE, fixed effects; SE, standard error; OLS, ordinary least squares.
*$p < 0.10$.
**$p < 0.05$.
***$p < 0.01$.

task lights. Indeed, qualitative interviews revealed that the lamp design made difficult the sharing of the light, and this was seen as a significant drawback to the users [2].

Why are the results on solar lamps different from those on the SHS? The reason is probably that these lamps are not regarded as a substitute for grid-powered lighting. Households experiencing relative deprivation do not want SHS because they believe they have the right to grid electricity. At the same time, their dissatisfaction with lighting seems to increase their willingness to pay for a related product that is not perceived as a direct substitute but as an incremental improvement.

Overall, the findings suggest that relative deprivation could have a negative effect on the adoption of some solar products. While interest in solar lanterns could increase, the development of bigger and more significant technologies, such as SHS, would suffer from relative deprivation with respect to electricity. The most plausible explanation for this pattern is that relative deprivation causes households to demand improvements in terms of grid extension. Because they live close to a power line, they are natural candidates for a grid connection. In contrast, households living far away from a power line must contend with alternatives such as SHS.

6. CONCLUSION

This article has shown that relative deprivation changes people's perceptions of their energy poverty in Sub-Saharan Africa. Unelectrified households are less satisfied with their domestic lighting solutions but more optimistic about improvement if they live in the proximity of a power line, measured in terms of visibility from the home. The decrease in the likelihood of being satisfied is 4%. While not particularly large, the effect is also not trivial, and other control variables have similar coefficients in our regression equations.

The optimistic interpretation of these findings is that unequal access to electricity is subject to a self-correcting mechanism. When governments provide electricity to some but not all households, they provoke feelings of relative deprivation. If the government is accountable to the population, this relative deprivation could engender policy change. However, this requires functioning democratic institutions. Our findings cannot identify the conditions under which a country is capable of effectively electrifying rural areas, but fortunately, extensive case studies of successful approaches are available elsewhere [17,31].

There is much scope for further exploration. Our data unfortunately do not speak to the roles of modifying factors such as ethnicity or religion. Future surveys of relative deprivation and energy access could address this issue by collecting data on how individuals perceive relative deprivation when compared with different groups of people. Another promising extension pertains to the connection between relative deprivation and political participation. As Huntington and Nelson [32] argue, political participation in a developing society is a complex phenomenon with multiple forms and causes. Our results suggest that relative deprivation in regard to energy and other infrastructure access could create dissatisfaction and latent demand for policy change. Future research should explore the realization of this latent demand.

For policy, an interesting finding from the study is that relative deprivation might increase willingness to pay for small devices such as solar lamps and reduces household interest in SHS. This might suggest that households in Sub-Saharan Africa perceive solar-powered electricity as inferior to grid electrification and would refuse a stopgap measure as a substitute for grid access. As governments build more power lines, demand for SHS could decrease among households who are not connected, especially if SHS prices do not continue to decrease significantly. As long as connection charges remain at their current, extremely high levels in East African countries [27], the number of such households is bound to remain high. If Ethiopia, Kenya, Tanzania, and Zambia want to replicate Ghana's impressive performance in electrification, they must implement policies that reduce the cost of electricity connection to households. Perceptions of relative deprivation could contribute to this.

ACKNOWLEDGEMENTS

We thank Peter Alstone for sharing the data used in this article. We thank a seminar audience at Columbia University for their insightful observations on the research. Finally, we thank Catalina Angel, Michaël Aklin, Patrick Bayer, Peter Lund, and the anonymous reviewers for excellent comments on a previous draft.

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SUPPORTING INFORMATION

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Int. J. Energy Res. 2014; **38**:1727–1740 © 2014 John Wiley & Sons, Ltd.
DOI: 10.1002/er