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Pre-Analysis Plan: *Household Upgrade Decisions in Off-Grid Solar Services*

1. Study Rationale

The International Energy Agency estimates that more than 1.1 billion people worldwide lack access to electricity. While there is a growing consensus in the developed world that the most promising 'no-regrets' path to reducing carbon emissions is to electrify as many sectors as possible (Dennis et al., 2016), at current electrification rates many countries in these regions will not be able to meet the 2030 Sustainable Energy for All goal of universal energy access (International Energy Agency and World Bank Group, 2017, p. 23). Beyond simplified measures of access, many households with electricity continue to have poor quality of service which prevents the effective use of electricity for household and productive uses (Sovacool et al., 2016).

The market for off-grid electricity solutions (solar lanterns, solar home systems, and microgrids) continues to grow: as of 2016 there were over 100 companies focusing exclusively on solar lanterns and solar home systems (World Bank, 2016). Start-up companies are selling solar home systems in both SSA and India that provide enough electricity for lighting services, cellphone charging, and television (Bearak, 2016; McKibben, 2017). Beyond basic services such as lighting and charging, the market for "higher-margin products" such as fans and TVs is expected to grow to 7 million fans and 15 million TVs by 2020 (Bloomberg New Energy Finance et al., 2016). While many companies and donor organizations initially focused on providing lighting and basic charging via lanterns and solar home systems, but now recognize the importance of higher-margin products and services to their business models, such as appliances that use more energy, like TVs, irons, and refrigerators, or encouraging more productive uses, such as small shops and enterprises.

Key determinants of household decisions to upgrade or include appliances parallel those identified in the solar industry more broadly strengthening the market to providing consumers with information to make informed decisions about available options. Solar home systems allow for the use of more appliances and the opportunity to add appliances and upgrade systems to allow for new appliances. At times, this can result in exceeding the installed capacity of installed solar home systems (Baldwin et al., 2015), suggesting the need for system upgrades as more appliances are added. Marketing research on quality suggests that determinants of quality – both technical and non-technical – are influential in service models (Parasuraman et al., 1985). In this context, the shift towards energy as a service (Fell, 2017) rather than solely a technical purchase or solution, provides end-users the opportunity to be more engaged and active in energy decisions.

2. Survey Implementation

The questionnaire is entered into Qualtrics and collected using the Qualtrics off-line application for tablets. 360 households with experience with standalone solar home systems will be surveyed. The order of attributes will be randomized by household. Households will respond to 6-8 choices, the final number of choice sets will be determined by a pilot of the instrument (in the Appendix) in order to assess data quality. All respondents will first receive information on the study, including IRB protocol, and then will be asked the screening questions. Then this conjoint will be randomly varied with another conjoint survey on solar intermediaries for each household. Finally, all households will reply to a set of demographic questions at the end of the survey. We expect this survey to take about 45 minutes at each household.

3. Outcomes of Interest and Hypotheses

Substantial attention has focused on the purchase of technologies such as solar home systems (Bensch et al., 2018) while simultaneously calling for a focus on end uses of solar (e.g., appliances). This project aims to bridge these two by examining appliances used on or compatible with solar home systems. Overwhelmingly, studies point to cost (Bensch et al., 2018), income thresholds (Gertler et al., 2016), and credit constraints (Urpelainen and Yoon, 2015) as key inputs into the household decision process for solar purchases. This study examines the multidimensional nature of quality, including technical quality indicators, service quality, and payment options. Based on the previous literature our preliminary hypotheses are the following.

H1: Households are more likely to upgrade their solar home system if they are offered financing in a pay-as-you-go daily rate.
H2: Upgrades are more preferable if they are compatible with the grid.
H3: Households will upgrade with companies they knew of before the purchase.
H4: Households prefer to speak with someone in person if there is a problem.
H5: Households prefer to purchase appliances from someone who visits them at home.

Conjoint analysis can be conducted as rating or ranking and choices-based approaches, we propose to use only a choice-based approach with no rating portion (examples from Hainmueller et al., 2014 use both choice and rating in a single survey). Additionally, we use a paired conjoint design which evidence suggests better approxmiates real-world behavior than other survey options (Hainmueller et al., 2015). This approach allows for joint effect of different attributes on an overall judgment (Rao, 2014). For example, Oliveros and Schuster (2018) test attributes of politicians on voter choice and test attributes of bureaucrats on perceptions of corruption and clientelism. Other work used this method to study preferences for smart green stormwater infrastructure (Meng and Hsu, 2019). Compared to more traditional survey methods Hainmueller, Hopkins, and Yamamoto (2014), argue that conjoint surveys can be used to estimate "the effects of causal components on respondents' stated preferences without bias" (p. 3) and propose the value of conjoint surveys is that they can jointly measures the influence of attributes on the choice of interest, this better measures multidimensional preferences and reflects a choice based on "packages as a whole" (Horiuchi et al., 2018) which more closely approximates real choice settings. Data will be analyzed using a binomial logistic regression model (binary choice outcome) to determine the effect of different attributes on the stated choice preference of respondents (see Appendix). In addition to binomial logistic regression, we will also explore using the cjoint package in R (Oliveros and Schuster, 2018).

4. APPENDIX: Instrument

4.1. Screening Questions:

1. Are you able to understand Swahili?
2. Are you able to read Swahili?
3. Are you directly involved in making decisions about how to spend money in your household?
4. In the past twelve months, have you used a solar home system in your home? (A solar home system can support the use of multiple appliances, for example, lights, phone charging, and a radio and/or TV using a solar panel on your roof)
   a. When did you buy this solar home system?
   b. Where did you buy this solar home system?
   c. Is this your first solar home system?
   d. When did you buy your first solar home system?

4.2. Demographic Information

1. Head of Household (male/female)
2. Occupation of Head of Household
3. Source of Household Income
4. Budgeting decisions: husband, wife, or joint
5. Education levels (Head of household, husband/wife)
6. Ages (respondent, head of household)

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7. y size
    a. Number of school-age children
8. Participation in *chama* (lending group)
9. Ethnic group
10. Village name
11. District name
12. Previous experience with solar
    a. Where did you get your solar system?
    b. How did you hear about it?
13. Connection to electricity grid (yes/no)
14. Hours per day of electricity
15. Frequency of all-day outage
16. Electricity during the part of the day they need it
17. Appliances in household (lights, charging, radio, TV, etc.)
18. Monthly household income
19. Monthly amount spent on electricity

4.3. <u>BLOCK: Solar Upgrades</u>

Introduction: We are interested in understanding how you make decisions about upgrading your solar home system to include more appliances. By upgrade, we mean have you added additional capacity (new panel, battery) to allow you to put a new or larger number of appliances on your solar home system. For the purposes of this survey please imagine you are purchasing the solar system and appliances from the same company, at the same time. Have you upgraded your solar home system package/kit?

If yes, what did you add? You may select multiple.

If you have not upgraded your solar home system, imagine your current appliances no longer meet all of your needs and you want to upgrade your system. What appliance would you want to add? You may select multiple.

Imagine you are making that decision to upgrade your solar home system kit to include that appliance
and solar now, with that decision in mind please choose between the following options.

1. Which of the two service packages would you prefer?

Randomize the following variables and present as choices to respondents:

Pricing 1	54999 KSH (cash payment, all at once)	3000 KSH/month for 18 months	100 KSH/day for 18 months
Warranty (physical quality)	No warranty	1 year	2 years
Compatibility (physical quality)	can use with grid electricity	can use even if there is poor voltage	can use with another SHS
Recognition (corporate quality)	did not know of company before	knew of company before	
Service accessibility (interactive quality)	If there is a problem I expect no contact with company	If there is a problem a call center is enough	If there is a problem I expect to speak with someone in person
Product availability (interactive quality)	Solar compatible appliances available within a 45-minute walk	Solar compatible appliances available within a 60-minute ride (motorcycle)	Solar compatible appliances available from someone who travels to your home

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