Working paper

International Growth Centre

Powering Small Business

Understanding the Impact of Solar Energy Under Different Pricing Schemes

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Final Project Report for Powering Small Business: Understanding the Impact of Solar Energy Under Different Pricing Schemes

William Jack and Tavneet Suri

I. Introduction

This report details the progress on the project "Powering Small Business: Understanding the Impact of Solar Energy Under Different Pricing Schemes" set up in Kenya in 2013.

587 million people (69.5% of the population) lack access to electricity in Sub-Saharan Africa. Retailers with poor access to electricity have limited means to keep their shops open at night. This limits their ability to operate during evening hours and reach customers who might be at work during the day. Solutions like kerosene do a poor job of lighting the room and have negative health effects. Besides, traditional off-grid solutions require significant one time investments, making them unrealistic for poorer consumers.

This project studies the pricing schemes for a new solar technology that combines solar power, mobile repayment, and mobile enforcement. We are partnering with Angaza Design who will roll out 1000 units of their Solite-3 – a solar-powered device that provides light and charges phones. The devices allow payment via mobile money and monitoring of payments with enforcement upon non-payment. This enables Angaza to ask retailers for a very low and affordable down payment and allows them to gradually pay back the full amount of the device over time, based on use and at no transaction cost (PAYG using M-PESA, the current mobile money system in Kenya).

The project aims to study three broad sets of research questions:

(i) What is the impact of electricity (and light) on small retailers? Retailers may be able to keep their shops open later, and could get additional income from phone charging. They may also offset current kerosene or lamp expenditures.

(ii) What is the impact of mobile repayments and mobile enforcement on asset purchases relating to take-up, default rates and use? This is a very cheap and simple way to enforce credit contracts in environments where such enforcement is usually extremely costly and involves door to door, group visits and in person collections.

(iii) What is the impact of varying the pricing structure? What is the effect of different per-hour prices on take-up, default rates and energy consumption? The variation in the price structure also helps us determine how to optimally price such an asset in a developing country environment.

The study is being conducted in low-income peri-urban areas of Nairobi, Kenya.

II. Experimental Design and Research Questions

Angaza Design has agreed to offer 1000 Solite-3s as part of the research study. We have selected about 1800 retailers that satisfy Angaza's criteria as potential clients. They will be randomly assigned to five treatment groups and one control group: each group having 300 retailers. Retailers in the five treatment groups are offered the Solite-3 under varying conditions which allows us to understand the impact of different pricing structures and technologies.

Pricing options

There are three prices at which hours of power can be purchased:

- Basic service price: Kshs 15
- Valued user price: Kshs 10
- Default price: Kshs 20

Option 1: Basic service plan (Pay As You Go)

Customer can purchase power in any increments at a per-hour price of Kshs 15. There is no weekly minimum purchase required. Payments continue until the simple undiscounted sum reaches the capital cost of the product: Kshs 8,000.

Option 2: Valued user plan with enforcement

Customer can purchase power in any increments at a per-hour price of Kshs 10 , but over the course of any calendar week, starting on the day of the week on which the unit first enters service, at least Kshs 150 much be deposited.

If in a given calendar week the customer deposits less than Kshs 150, then the customer enters a default period. Starting on the first day of the following week, the per-hour price switches to the penalty or default rate of Kshs 20. The customer faces this per-hour price until Kshs 150 have been deposited within a week. At that point, the customer reverts to paying a per-hour price of Kshs 10 for the rest of the week. At the beginning of the next week, the customer is deemed to be "in good standing" and faces a per-hour price of Kshs 10, and must deposit Kshs 150 again. However, if during the default period the customer does not deposit Kshs 150 within the first week, the per-hour price remains at the default rate, Kshs20, into the next week. This continues until during the course of one calendar week the customer has been able to pay a total of Kshs 150.

Option 3: Valued user plan without enforcement

This is the same as Option 2, but the requirement to deposit Kshs 150 each week is not enforced. That is, if less than Kshs 150 is deposited in a given week, no change occurs in the following week. Option 3 is similar to Option 1 but with simply a lower per-hour price.

Treatment arms

With these three pricing options, we defined the following treatment groups

Treatment A: Pricing option 1 offered

Treatment B: Pricing option 2 offered

Treatment C: Pricing option 3 offered

Treatment D: Pricing option 2 offered, but converted to option 3 *ex post*.

Treatment E: Pricing option 1 offered, but converted to option 3 *ex post*.

This allows us to study 3 main questions:

(1) What is the impact of electricity?

To understand the impact of electricity on small retailers, we are administrating two baseline surveys, three follow-up surveys and one endline survey and comparing relevant outcomes between retailers offered the possibility to purchase a SOlite-3 in the treatment group with the highest take up –likely to be treatment group C. These surveys collect data on business outcomes such as profits, revenue, operating costs and operating hours. Through this randomized design, we will quantify the impacts of providing light and energy to small retailers. We expect these benefits to include higher profits due to stores being open longer and phone charging services being provided to customers.

(2) What is the impact of mobile repayments and mobile enforcement?

The Solite-3 automatically collects usage data in real time and Angaza's internal systems collect repayment data. Angaza Design has agreed to provide us with full access to this information. By comparing adoption rates, repayment rates, usage and other outcomes between treatment groups B and D, we can quantify *the treatment effect of enforcement*. Retailers in both treatment groups B and D have been offered a low per hour price at the condition of being financially punished if they do not use the Solite for more than Kshs 150 per week. Although retailers in treatment group D have decided to purchase the product at these same conditions, the punishment is not enforced ex post. By comparing both of these groups, we can determine the differences in behaviors when enforcement is cut (Treatment group D). Similarly, the comparison between treatment groups C and D highlights the *selection effect of enforcement*. Indeed, retailers in both groups do not get financially punished even if the weekly Kshs 150 threshold is not reached. Average outcome differences might however exist as retailers in both groups might have different characteristics having initially chosen to purchase the product under different pricing schemes (each group's self-selection was under different pricing terms).

(3) What is the impact of varying the price structure?

Groups are offered different per hour energy prices (Kshs 10 or Kshs 15) and comparing usage, repayment rates and business outcomes between these groups will help us understand the importance of pricing and price discrimination for small retailers. What impact on take up does an increase on per hour price have? Does a lower per hour price encourage clients to consume more electricity and repay more quickly or does it select unworthy clients who default? As part of this process, we will work closely

with Angaza Design to develop an optimal pricing structure that will maximize both adoption and repayment rates.

Similarly to above, the comparison between Treatment group A (Kshs 15) and E (Kshs 10) allows us to quantify *the treatment effect* of prices variation on business outcomes but also on repayment rates and electricity usage. Comparing Treatment C to E allows us to calculate the *selection effect of pricing* as retailers in both groups enjoy a low per hour price although those in E had initially purchased the device assuming a higher per hour price. Therefore this comparison highlights the difference in the types of customers who self-select in different pricing schemes.

Summary of the Experimental Arms

Treatment Group	Name of Group	Price per hour	N	Role of Enforcement		Role of per hour price	
Treatment A	Basic service plan	Kshs 15	300			Treatment effect	
Treatment B	Valued user plan with enforcement	Kshs 10– default Kshs 20	300	Treatment effect			
Treatment C	Valued user plan without enforcement	Kshs 10	300		Selection effect		Selection effect
Treatment D	Valued user plan with enforcement dropped ex post	Kshs 10	300	Treatment effect	Selection effect		
Treatment E	Rebate on basic service plan ex post	Kshs 10 (coming from Kshs 15)	300			Treatment effect	Selection effect
Control Group	No Solite		300				

III. Changes

III.a Location

In late 2012, the project was moved from Tanzania to Kenya after the implementers (Angaza Design) realized that the distribution of solar panels in Tanzania would be much costlier than expected. Their main distributing partner in East Africa is Sunny Money whose presence in Tanzania is too limited for a project this size. In addition, the high prevalence and use of mobile money in Kenya meant that the take up of these solar lights would be much higher in Kenya since mobile money is used to pay off the asset. The penetration of mobile money is much lower in Tanzania which would have imposed further costs as

retailers would also have to be trained to use mobile money. The research team conducted a scoping visit to Tanzania and also supported this move to Kenya.

III.b. Timeline

Although the length of the project remains the same, the project's timeline has been shifted by a few months due to (a) the change in location (b) the Kenyan General Elections and (c) the delay in delivery of the Solite3 units. Firstly, the launch of the project was delayed due the change of location. Secondly, Kenya's presidential elections on March 4th meant the project activities had to be slowed down and minimized during the few weeks around these events. Thirdly, Angaza Design has experienced delays in shipping the units to Kenya, which are necessary before the start of the Implementation phase. We are therefore hoping to start implementing end of April 2013. However, this delay has had no material impact on the IGC component of the funding. The IGC funding was used to cover a portion of the capital costs of the panels; the listing exercise we conducted in Nairobi to identify the relevant sample of participating retailers; the first two baseline surveys across all 1800 retailers in the sample, the second of which was just completed at the end of March, as we detail below. We have additional funds to cover the rest of the study.

III.c. Experimental Treatment Groups

Experimental Treatment Groups were modified and increased from 5 to 6 (including the control group). This was motivated by (i) on the ground piloting by our partner distributor and feasibility assessments and (ii) technical limitations of Angaza's products and internal systems.

IV. Progress to Date

The team invested significantly in setting up and piloting the project. A number of exploratory trips and procedures were conducted both in Tanzania and in Kenya, which led to a shift of location to the latter and the selection of adequate peri-urban areas in Nairobi. Eight neighborhoods were selected based on (i) electrification rate (ii) density of retailers and (iii) type/size of retailers. The eight areas are Kawangware, Kangemi, Uthiru, Waithaka, Dagoretti, Kikuyu, Kinoo and Wanginge.

In January 2013, our Research Team on the ground conducted a detailed census of all small retailers in these neighborhoods -around 9440 retailers were recorded. 2300 of those have no access to electricity and are forced to either shut before dark or use kerosene or candles at great costs. These retailers could benefit hugely from solar energy and therefore became our target sample.

The first Baseline study was rolled out in February 2013 and took about three weeks to complete. 76% of the sample was successfully surveyed (summary statistics reported below). The second Baseline

survey started in mid-March 2013 – after a break due to the General Election - and has been completed. The implementation/distribution of the solar lights is scheduled for the end of April.

The Research Team and Angaza Designed partnered with Sunny Money, a global distributor of solar lights operational in East Africa to set up distribution and servicing of the devices. Sunny Money has successfully tested the products to confirm they meet their standards as well as national guidelines. They have also set up a dealer network in the relevant Nairobi neighborhoods to facilitate distribution. Indeed, 34 dealers were selected and recruited. They will be trained intensively to sell the solar devices to the retailers, to offer technical assistance during set up and after-sale advices. Sunny Money is responsible for this training. The dealers will only sell a device to retailers in exchange of a voucher that will be distributed during a marketing round carried out by the Research Team. The purpose of these vouchers is to make sure (1) retailers in the control group do not purchase these solar lights (no transfers from the treatment groups to the control group) and (2) the retailers receive the correct treatment, depending on which treatment group they belong to. All training and marketing material and logistics have been organized for a rapid launch as soon as the products arrive in Nairobi.

Next, we report on some of the findings from the census we conducted as well as the first baseline. The second baseline is currently being cleaned.

V. Summary Statistics:

V.a Listing

In January 2013 we conducted a listing of all small retailers in the eight areas of study. The research team listed 9,437 small retailers. The table and graph below show the distribution of the 9,437 retailers in the eight areas visited.

Graph 1:

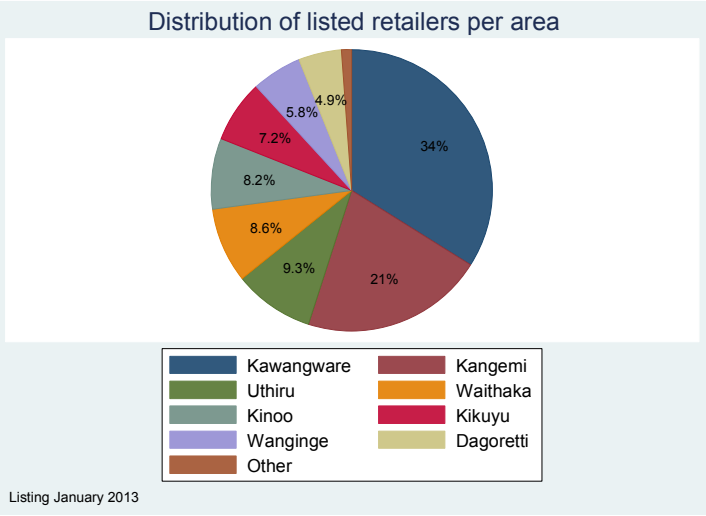
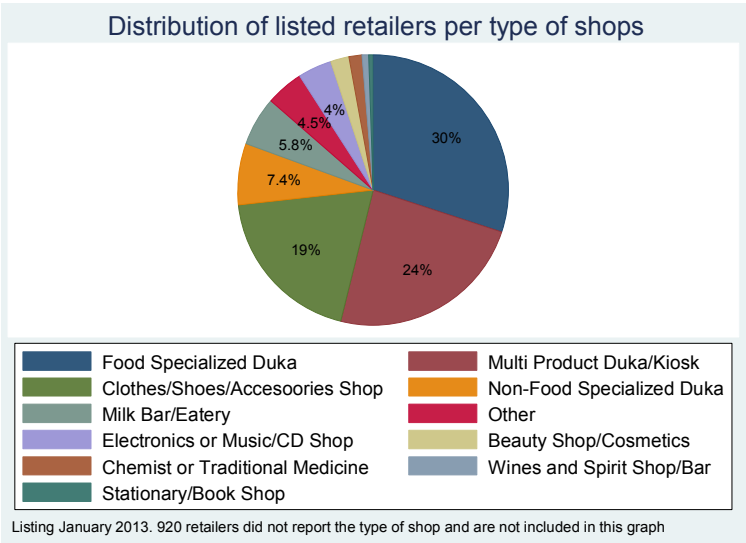


Table 1: Distribution of listed retailers per area

Area	Freq.	%
Kawangware	3,203	33.94
Kangemi	1,983	21.01
Uthiru	873	9.25
Waithaka	811	8.59
Dagoretti	463	4.91
Kikuyu	678	7.18
Kinoo	772	8.18
Wanginge	543	5.75
Other	111	1.18
Total	**9,437**	**100**

The listing included all small retailers, irrespective of the type of shop they own. 30% of the listed retailers who allowed us to report their type of shops own small kiosks and specialize in one item, such as green grocers (Graph 2).

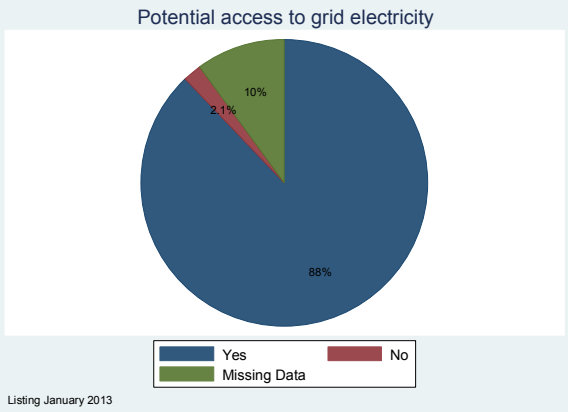
Graph 2:



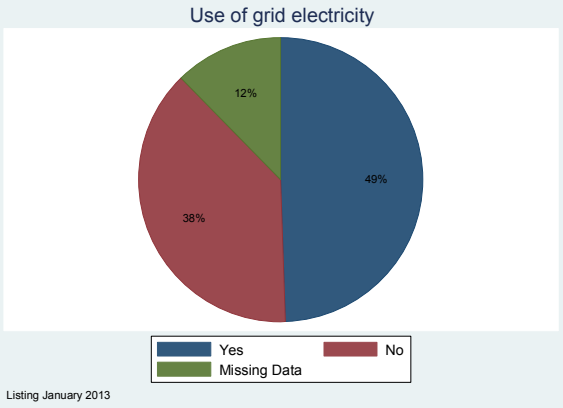
Access to electricity:

Access to electricity also varies across these retailers. Although grid electricity seems to be available for more than 88% of the retailers listed, only 49% report using grid electricity (see graphs 3 and 4).

Graph 3:



Graph 4:



When retailers do have access and use grid electricity, they seem to rely primarily on it. Indeed, most of the 49% who report using grid electricity list electricity as their first source of energy (48% of listed retailers).

Table 2: Prime source of energy for listed retailers

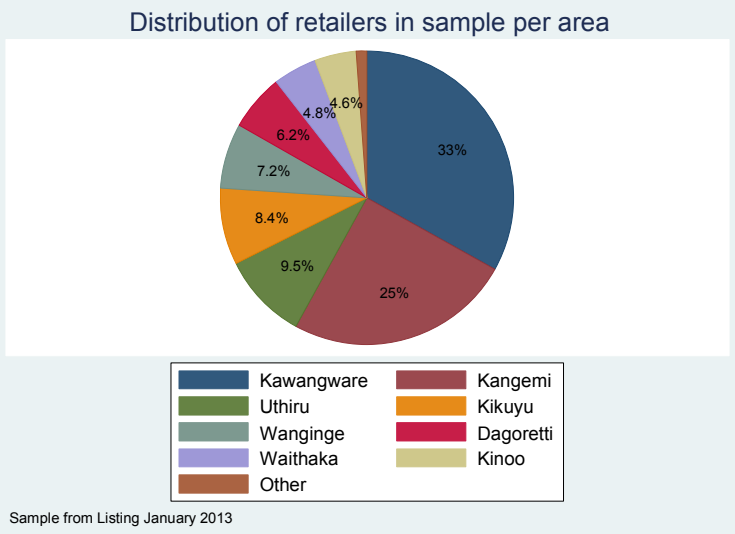
Sources of energy for shop	Freq.	%
Electricity	4,550	48.21
Coal	18	0.19
Kerosene	1,083	11.48
Other oil	8	0.08
Gas (cooking gas, etc)	8	0.08
Solar	63	0.67
Wood	3	0.03
Candles	213	2.26
Batteries	119	1.26
Other	1,985	21.03
Missing	1,387	14.7
Total	**9,437**	**100**

Out of the 9,437 retailers listed, we selected 2,359 (25% of the listing) who had agreed to be included in the listing and who did not use electricity as their first source of energy. This selection was based on the assumption that a solar powered light and phone charger would be most beneficial to retailers with limited access to electricity. The 2,359 retailers now constitute our sample.

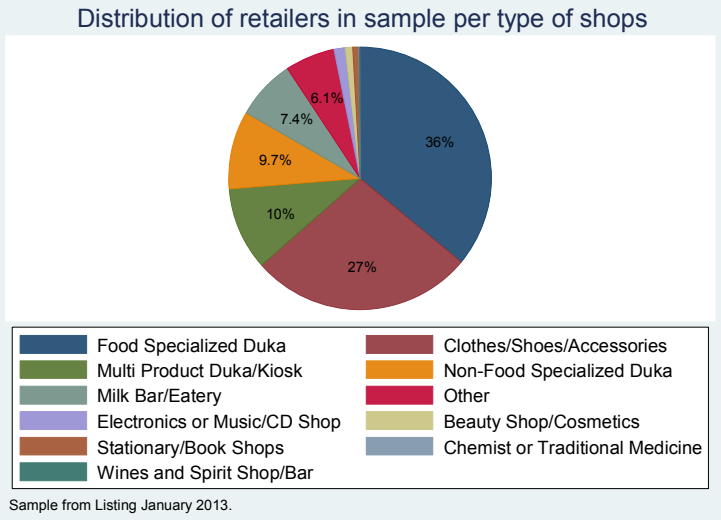
V.II: Baseline 1 statistics

Baseline 1 was conducted in February 2013 and 1,783 surveys were completed[1] (76% of the sample). The sample selected remains representative of the listing. As an example, more than 30% of our sample is located in Kawangware and more than 20% in Kangemi, which matches the listing's distribution of locations (Graph 5). Similarly to the listing, food specialized kiosks form more than 30% of our sample (Graph 6).

Graph 5:



Graph 6:



[1] The remaining 14% were not surveyed due to refusals or retailers not available/found at the time of survey.

Revenues/Profit:

From our Baseline 1 data, the sampled retailers make approximately 600 Kenyan shillings (US $7) of profit daily and Kshs 1700 (US $20) of revenue daily (Table 3). The down-payment for the Solite-3 (Kshs 500) is therefore equivalent to about one day of profit.

Table 3: Daily Profit and Revenue for Retailers in Sample:

	Daily Profit Normal Day	Daily Profit Good Day	Daily Profit Bad Day	Daily Revenue Normal Day	Daily Revenue Good Day	Daily Revenue Bad Day
N	1632	1638	1629	1681	1692	1682
Mean	586.6	1165.4	302.8	2307.2	3994.6	1310.5
Min	0	0	0	0	0	0
Max	5000	10000	3000	20000	30000	10000
p25	200	400	100	800	1000	400
p50	400	600	200	1500	2300	800
p75	700	1400	400	3000	5000	1500

Table 4: Monthly Profit and Revenue for Retailer in Sample:

	Average Monthly Profit	Profit Last Month	Profit 2 Months Ago	Profit 3 Months ago	Average Monthly Revenue	Revenue Last Month	Revenue 2 Months Ago	Revenue 3 Months Ago
N		1558	1462	1410		1537	1446	1391
Mean	12807.1	11166.0	15071.6	12183.8	47976.0	43084.9	54488.2	46355.0
Min		0	0	0		0	0	0
Max		95000	120000	90000		384000	462000	400000
p25		4000	5000	4000		12000	14000	12000
p50		7500	10000	8000		25000	30000	27000
p75		15000	20000	15000		54000	70000	60000

One of our main research questions is the impact of the solar energy on the profits of the retailers. This could happen via two mechanisms. First, shops can open for longer hours due to the additional light and second, retailers could set up a phone charging business, adding a new revenue stream.

Hours of business:

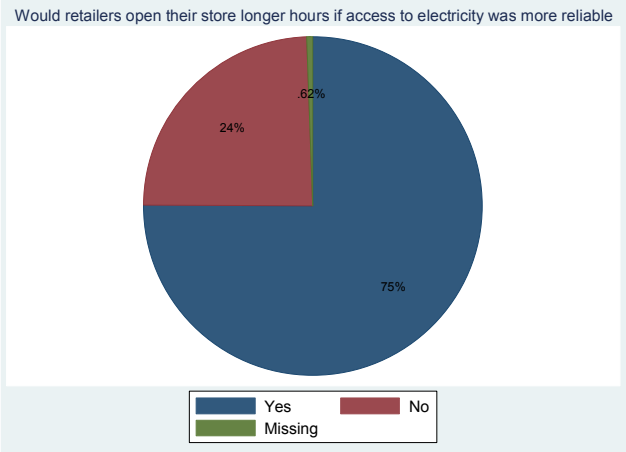
Our baseline data shows that an average retailer opens his/her shop 10 hours a day and 6 days a week (Table 5). He/she opens before 6 am three days a month and closes after 6pm 22 days. Interestingly,

73% of retailers would open for longer hours if electricity was cheaper or more reliable. If they could open for longer, 41% would want to open earlier and 69% would open later (Graphs 7 to 10).

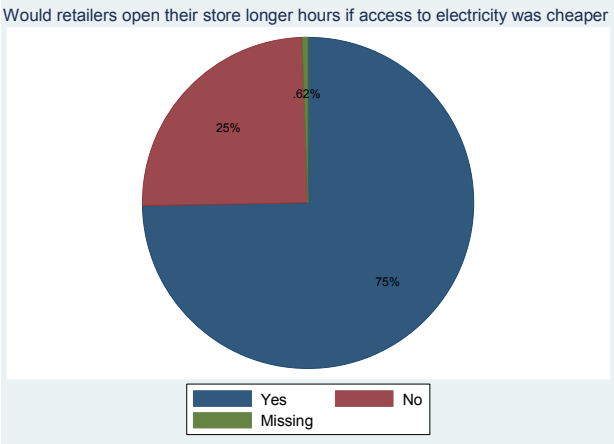
Table 5: Business Hours and Days for shops in sample

	Number of hours open per day	Number of days open per week	Number of days open before 6 am per month	Number of days open after 6pm per month
N	1776	1778	1777	1773
Mean	10.9	6.4	3.7	22.1
p25	9	6	0	20
p50	11	6	0	27
p75	12	7	0	31

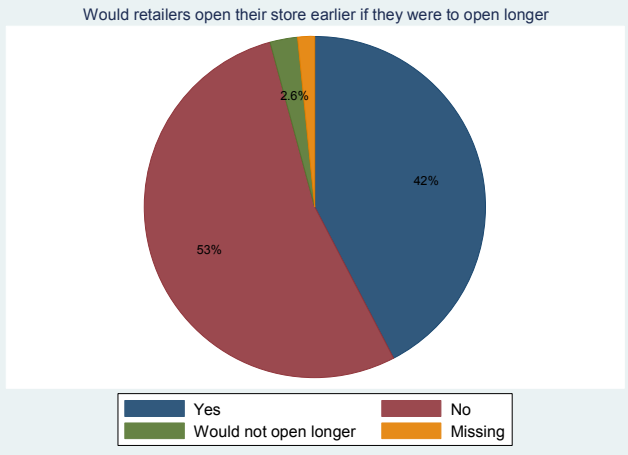
Graphs 7:



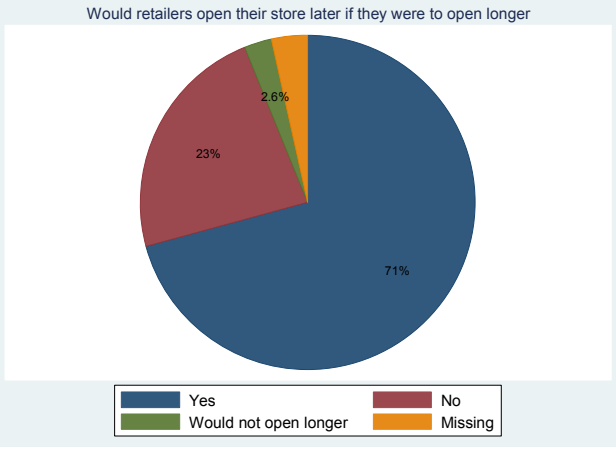
Graph 8:



Graph 9:

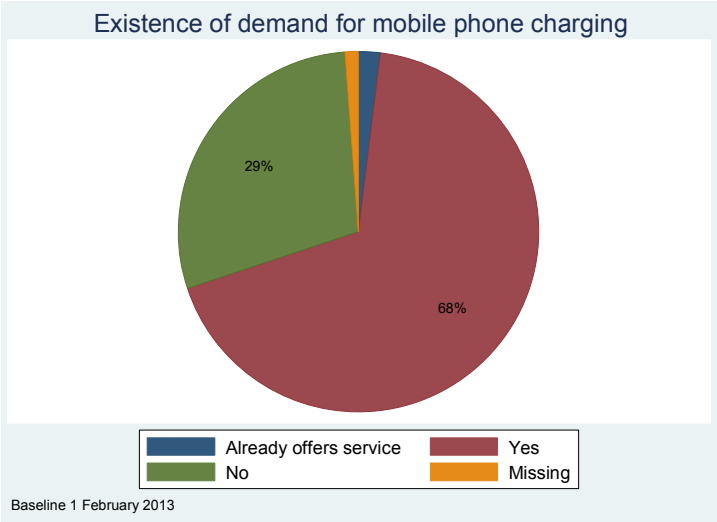


Graph 10:



As highlighted previously, profits could also be increased if the Solite-3 is used to set up a phone charging business. Currently less than 2% of the retailers own such a business but an additional 68% would consider offering this service if they had access to the Solite-3 as the demand seems to exist (Graph 11).

Graph 11:



Sources of energy:

Finally, this project might create a shift from traditional energy sources to solar power. Coal and Kerosene (in that order) seem to be popular energy sources for these retailers. Currently, an average retailer spends for all energy purposes Kshs 145 ($ 1.70) on Kerosene per month and Kshs 300 ($3.50) on Coal. If we restrict the analysis to those who do use Kerosene, an average user will spend Kshs 465 ($5.50) per month on Kerosene and Kshs 3000 ($35) on Coal (Tables 6 and 7)

Table 6: Monthly Spending on Energy (dropping the top percentile)

Monthly Spending on Energy (dropping the top percentile)						
	Monthly Expenditures on Batteries	Monthly Expenditures on Candles	Monthly Expenditures on Coal	Monthly Expenditures on Electricity	Monthly Expenditures on Gas	Monthly Expenditures on Kerosene
N	1737	1737	1741	1725	0	1731
Mean	22.8	20.9	296.9	9.7		144.0
Min	0	0	0	0		0
Max	540	600	8400	563		1800

p25	0	0	0	0	0
p50	0	0	0	0	0
p75	0	0	0	0	200
p90	40	0	6	0	600
p95	200	200	2400	0	750

Table 7: Monthly Spending on Energy for those using the source (dropping the top percentile)

Monthly Spending on Energy for those using the source (dropping the top percentile)						
	Monthly Expenditures on batteries	**Monthly Expenditures on Candles**	**Monthly Expenditures on Coal**	**Monthly Expenditures on Electricity**	**Monthly Expenditures on Gas**	**Monthly Expenditures on Kerosene**
N	178	169	175	59	0	540
Mean	222.1	214.9	2953.6	283.4		464.5
Min	8	6	6	40		1
Max	540	600	8400	563		1800
p25	120	50	960	120		240
p50	200	240	2400	300		335
p75	300	300	4650	400		600
p90	450	500	6200	500		900
p95	480	600	7200	520		1200

For lighting purposes, most retailers use kerosene – in our sample, 460 retailers use kerosene compared to 130 who use candles, the second most used lighting input. Kerosene is not only the most used source of energy for lighting, an average retailer also invests in Kerosene the most. Kshs 116 ($1.50) is spent on Kerosene every month to provide light to their retail shop whereas Kshs 14 ($0.15) is invested in candles monthly (Table 8). Similarly to the analysis for expenditures in energy, if we only focus on the retailers who do use that input, expenditures in kerosene amounts to Kshs 440 ($5) per month for an average user whereas only Kshs 180($2.10) are invested in candles. Interestingly, coal seems very expensive for lighting (Table 9).

Table 8: Monthly Spending on Lighting (dropping the top percentile)

Monthly Spending on Lighting (dropping the top percentile)					
	Monthly Expenditures on Batteries	Monthly Expenditures on Candles	Monthly Expenditures on Coal	Monthly Expenditures on Gas	Monthly Expenditures on Kerosene
N	1733	1728	1745	0	1733
Mean	9.8	13.8	7.5		116.6

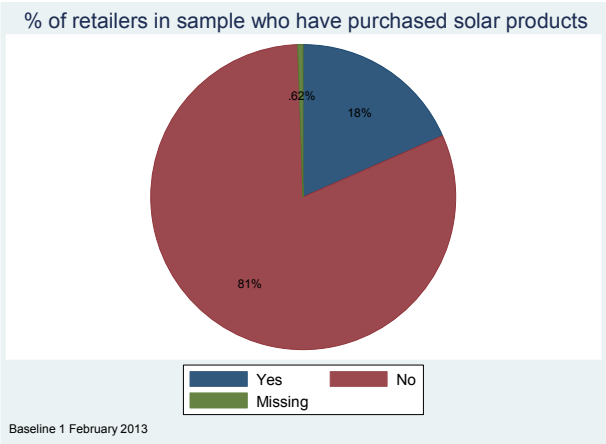
Min	0	0	0	0
Max	480	560	1440	1600
p25	0	0	0	0
p50	0	0	0	0
p75	0	0	0	60
p90	0	0	0	500
p95	0	80	0	620

Table 9: Monthly Spending on Lighting for those using the source (dropping the top percentile):

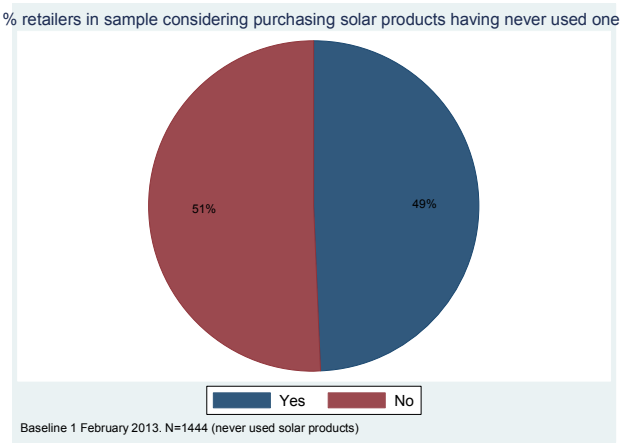
Monthly Spending on Lighting for those using the source (dropping the top percentile)					
	Monthly Expenditures on Batteries	Monthly Expenditures on Candles	Monthly Expenditures on Coal	Monthly Expenditures on Gas	Monthly Expenditures on Kerosene
N	80	131	22	0	458
Mean	212.9	181.4	598.5		441.2
Min	3	3	9		3
Max	480	560	1440		1600
p25	140	40	200		220
p50	200	150	455		310
p75	280	300	1050		600
p90	400	310	1300		900
p95	450	500	1400		1040

Finally, 81 % of our retailers in our sample have never used solar products (Graph 12), although half of them have considered them (Graph 13). The main reasons for not purchasing solar products seem to be primarily because they are too expensive (34% of the responses) (Graph 14).

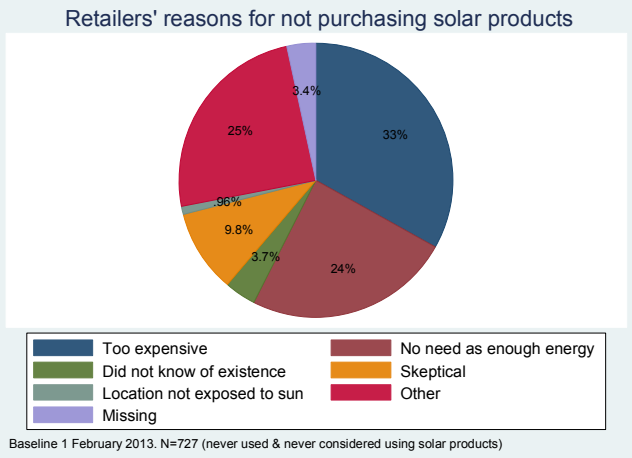
Graph 12:



Graph13:



Graph 14:



VI. Timelines and Future Project Output

VI.a. Timeline

As described in Section IV, by the end of March 2013, we have conducted multiple exploratory trips, a full census and two Baseline studies – the second Baseline data is currently being cleaned. The implementation is to begin end of April and will run for about a month, depending on take-up and the need for additional marketing rounds. Three follow-up surveys and one endline survey will then be carried out from July to November 2013. As mentioned, we will intensively follow just one treatment group and the control group.

The project is heavily co-funded by other sources and co- funding will cover for the remaining steps. We expect to have results by the end of 2013.

VI.b Project output

Analysis will be based on two sources of data: (1) data collected by the Research Team during baseline and follow–up surveys and (2) electronic data collected by Angaza including purchasing date, energy usage, frequency of top-ups, amount spent, repayment and default rates, etc. Angaza's electronic system also collects usage data separately for the mobile phone charging and for the light.

Using the data collected, we expect to answer the three research questions outlined above. Firstly, we will measure the impact of solar energy on businesses' profits, revenues, working hours and energy consumption. Secondly, we will determine whether enforcement is necessary for repayment in these environments and whether it affects usage, repayment and default rates. Thirdly, we will analyze the

pricing structure and quantify the importance of non-linear pricing on energy consumption and default rates. We hope that this will contribute to emphasizing the importance of solar energy in East Africa and how this can benefit poor retailers who may be unable to make the large investment costs needed for solar panels. We also hope to show the importance of asset based loan financing and how mobile money repayment and enforcement can reduce upfront costs and increase take-up. Finally, the data collected will help Angaza and other companies select the best pricing scheme (the data in Baseline 1 was already used to determine adequate pricing of per hour energy).

VII. Conclusion

This project studies the take up, pricing and impact of solar panels in a developing country context. These are important questions for an environment such as that faced by poor small scale retailers in Kenya where liquidity constraints prevent them from making productive investments. Given our baseline data on these retailers, it is clear that solar power could have immense gains, either by allowing them to keep their stores open later or by reducing their expenses on kerosene and batteries, the costs of which are reasonably high. This project aims to first look at the impacts of these solar panels. Second, we test various pricing mechanisms of the asset to understand what best trades off take up and default on the asset.

The IGC funding was crucial in the setup of the project. As mentioned above it was used to scope out locations for the project, cover some capital costs of the panels, and to conduct a census and two baseline surveys. We have additional funding to cover the parts of implementation we are responsible for as well as the follow-up surveys.

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