CROSSBOUNDARY

Study Design: Appliance Financing 2.0 Productive Use
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Executive Summary

This study tests whether offering productive use appliances, plus financing to purchase those appliances, alongside electricity is a profitable service addition for mini-grid developers.

The primary objective of the study is:

1. Determine what impact offering productive use appliances, plus financing to purchase those appliances, has on (1) the economics of mini-grids, (2) mini-grids' loads, and (3) customer wellbeing.

The study targets customers of currently operating mini-grids in Africa. The study will be conducted on sites where the community is newly offered productive use appliances on set financing terms. Appliances and financing to purchase those appliances will be offered to all current and potential customers at selected site(s).

The study will assess the impact of offering productive use appliances, plus financing to purchase those appliances, alongside electricity on three principal matters: (1) grid economics, (2) grid load, and (3) customer wellbeing. ARPU, program profit (or loss), and proportion of energy consumed during the day, among other metrics, will be used to analyze the impact on grid economics. Grid load will be assessed by measuring energy delivered. […] Control sites will be used to compare changes observed at treatment sites.

The study will be delivered by the Operator, who will organize support from technical advisors and other third parties as necessary. The Study Partners will provide funding for the study, collect all relevant data, and analyze the results as they pertain to each hypothesis. The results will be made publicly available on an anonymized, aggregated basis. The study is expected to run over a one-year period, beginning [date].

Study Partners

The following table outlines the role of each partner involved in the study.

Partner	Role
Funder	• Provides funding • Offers strategic oversight for the study
CrossBoundary (CB)	• Manages all aspects of project • Leads study design • Leads data collection, including surveying, and data cleaning • Leads analysis and communication of study results
Energy4Impact (E4I)	• Disburses and monitors funds provided to Operator • Supports analysis and communication of study results
Operator	• Provides insight into study design • Operates the mini-grids involved in the study and leads site implementation of study • Supplies data to CrossBoundary and other partners for analysis
Other partners	**Academic institutions:** • Supports study design • Supports analysis and communication of study results **Third parties (as identified):** • Supports Operator in site implementation of study

Introduction

Mini-grids are emerging as a viable technology to accelerate access to electricity in Sub-Saharan Africa. However, for mini-grids to become sustainable and scalable commercially, profitability must improve. This study seeks to improve grid economics by answering the question: can developers increase customer consumption, and thus revenue, by offering productive use appliances, plus financing to purchase those appliances, alongside electricity?

Demand for electricity in communities served by mini-grids is limited, in part, by people's need for power. To realize the full benefits of electricity, individuals must have access to resources facilitating that need, foremost of which are basic household electrical appliances. The upfront cost of appliances can be a major barrier to purchase, particularly in communities that do not typically have access to credit. Appliance financing schemes offer a promising solution to overcoming this barrier, thereby spurring the beneficial use of electricity and increasing demand within communities. Offering appliances and supporting financing is a compelling

business line to add to a mini-grid project and one the mini-grid operator can potentially manage directly, thus improving overall grid returns.

This study, therefore, seeks to:

1. Determine what impact offering productive use appliances, plus financing to purchase those appliances, has on (1) the economics of mini-grids, (2) mini-grids' loads, and (3) customer wellbeing.

The study targets customers of currently operating mini-grids in Africa. The study will be conducted on sites where the community is newly offered productive use appliances on set financing terms. Appliances and financing to purchase those appliances will be offered to all current and potential customers at selected site(s).

Experimental Design

Hypotheses

The following table details the hypotheses the study will test and how each will be measured. See *Annex 2* for hypotheses focused on customer wellbeing that all studies will consistently test. **Treatment sites** are defined as sites where productive use appliances are offered; **control sites** are defined as sites where no appliances are offered.

Hypothesis	Metric	Source
Grid Economics		
1. ARPU at treatment sites will be 10% higher than at control sites after one year (after adjusting for baseline ARPU differential between sites).	• ARPU	• Smart meters
2. The additional revenue from increased consumption and interest payments on appliances will cover the total costs to the operator of managing the program, including all direct and indirect costs*. ***Consist of: delivering appliances, managing loan repayments***	• Profit (or loss) of program	• Developer data

Hypothesis	Metric	Source
3. Consumption at treatment sites will shift to increased daytime usage. **a. ACPU during daylight hours (10am – 6pm) at treatment sites will be 25% higher than that at control sites after one year (after adjusting for baseline ACPU differential between sites).** **b. The fraction of total energy consumed during daylight hours (10am – 6pm) at treatment sites will be 5 percentage points higher than that at control sites after one year.**	• ACPU • % of total daily consumption occurring during daylight hours (10am – 6pm)	• Smart meters
4. Historically higher-user customers will exhibit the highest repayment rates at treatment sites.	• Repayment rate, segmented by customer quartiles	• Developer data
Grid Load **5. Solar mini-grids can sustain the load and meet the technical requirements of common productive use appliances, such as grain mills and welders.**	• Energy delivered as % of maximum theoretical energy generated	• Smart meters and developer data

Site and Participant Selection

Treatment sites will be chosen according to where the Operator has current operations and offering productive use appliances is feasible. Control sites will be chosen to resemble treatment sites as closely as possible, based on population, geography, profile and use of customers, and tariff structure.

All sites are eligible to serve as treatment sites; however, priority will be given to those sites meeting the following criteria:

- At least 100 customers
- At least six months of customer consumption and billing data
- Capability to automatically measure customer consumption and payment
- Reasonably high ARPU levels
- Sufficiently large load to sustain the use of productive use appliances

See *Annex 3* for Operator-specific site selection information.

Participants are those households who choose to purchase productive use appliances. All households considered members of the community or village will be given the opportunity to purchase productive use appliances.

Duration

The study is expected to run one year, starting as soon as possible upon the signing of the Operator Agreement. The projected timeline of the study is [date] – [date]. Early results will be analyzed after three months and quarterly thereafter.

The study's duration may be adjusted following initial results or any unforeseen circumstances.

Prototype-Specific Design Decisions

Productive Use Appliance Choice

Productive use appliances offered to study participants will be chosen based on the following inputs:

- Customer demand
- Mini-grid sustainability
- Operator feasibility

Productive Use Appliance Pricing

Pricing for each productive use appliance will be based on the wholesale cost of that appliance. Loan terms will be set to reflect commercial standards.

See *Annex 3* for Operator-specific design information.

Budget and Disbursement of Funds

The Operator is responsible for providing a budget that accurately reflects the cost of running the study in excess of standard operations. See *Annex 3* for Operator-specific budget information.

Prior to receiving funds, the Operator must submit the following:

- Approved budget
- Signed Operator Agreement (consisting of the Grant Agreement and Study Design)
- Historical remote monitoring data, as available
- Site economic data

Funding of the budgeted amount to support the study will be disbursed by Energy4Impact to the Operator in a single payment upon submission of all required materials.

The Operator is required to maintain a record of all costs incurred in implementing and running the study and must provide receipts reflecting the totality of costs to Energy4Impact. The Operator agrees to use funds solely for the purposes of the study.

Energy4Impact is responsible for monitoring the use of funds for the purposes agreed with the Funder.

Implementation

Operator

The Operator is responsible for operating all sites involved in the study and implementing the prototype on selected treatment sites as agreed to in this Study Design. This involves but is not limited to the following:

- Procuring and distributing productive use appliances offered to study participants
- Managing study participants' repayment of loans on productive use appliances
- Communicating all relevant information to study participants

The Operator will lead in engaging all third parties involved in the study and is responsible for thoroughly researching and proposing all third party collaborations. The Operator is also responsible for identifying and procuring any licenses or other regulatory approval required to implement the prototype. See *Annex 3* for Operator-specific implementation information.

The Operator agrees to inform CrossBoundary of any occurrences that may affect electricity consumption or other study results, and identify customers affected by such interventions (e.g. changes in tariff or meter numbers). The Operator additionally agrees to disclose any other information pertinent to the study (e.g. GIS data).

Third Parties

There are no third parties involved in this study.

Licenses and other Regulatory Approval

No licenses are required to implement this study, apart from the standard licenses required to operate mini-grids in [country].

Data Collection

All data shared through execution of the study is protected by a direct Non-Disclosure Agreement with Energy4Impact, who in turn holds a Non-Disclosure Agreement with CrossBoundary. Data will only be shared with partners approved by the Operator as outlined in the Non-Disclosure Agreement on an aggregated and anonymized basis to protect customer information.

Through participation in this study, the Operator agrees to share three types of data: (1) remote monitoring and customer data, (2) prototype-specific data, and (3) site economic data. Additionally, the Operator agrees to allow CrossBoundary to collect survey data. The following

table details the data the Operator is required to share, or allow CrossBoundary to collect, as part of the study.

Data Type	Metric	Unit	Frequency & Timing
(1) Remote Monitoring & Customer Data	**Customer consumption**	kWh	Twelve months' historical *(as available)*, prior to disbursement of funds + monthly for duration of study
	Customer electricity payment	Local currency	Twelve months' historical *(as available)*, prior to disbursement of funds + monthly for duration of study
	Meter numbers with customer information	Various	Once, prior to disbursement of funds
(2) Prototype-Specific Data	**Productive use appliances purchased with meter number, purchase date and price, and delivery date**	Various	Monthly for duration of study
	Monthly customer appliance loan repayment	Local currency	Monthly for duration of study
	Profit (or loss) of program	Local currency	Quarterly for duration of study
	Energy generated	kWh	Quarterly for duration of study
(3) Site Economic Data	**As shown in *Annex 1***	Various	Once, prior to disbursement of funds
(4) Survey Data	**Various demographic, socioeconomic, and user experience data**	Various	Twice, prior to the prototype's launch and following the prototype's end

(1) Remote Monitoring and Customer Data

To evaluate the study's success, the Operator will share electricity consumption and payment data alongside smart meter numbers for all customers on control and treatment sites. This should take the form of raw smart meter data exhibiting the highest resolution available (e.g. individual payment records on a fifteen minute to hourly basis).

Historical consumption and payment data for the twelve months prior to the prototype's launch must be provided upon signing of the Operator Agreement, before disbursement of funds. In the case this data does not exist (e.g. a site involved in the study is newly constructed or yet to be built), the Operator will provide historical data for as many months prior to the prototype's launch as is available. Following the prototype's launch, consumption and payment data must be shared on a monthly basis for the duration of the study.

The Operator will share all consumption and payment data with CrossBoundary through the Lab's data platform, managed by Odyssey Energy Solutions, via API integration with the smart meter account. Should this not be feasible, the Operator will share all data as otherwise agreed to by both parties.

Additionally, to facilitate data analysis and survey conduction, the Operator will share a list of all meter numbers with customer name, customer ID, connection date, phone number, site, and site geographic coordinates. This information must be provided upon signing of the Operator Agreement, before disbursement of funds and may be uploaded to Odyssey.

(2) Prototype-Specific Data

Any prototype-specific data required to evaluate the study's success must be shared for control and treatment sites on a regular basis for the duration of the study. Data that will remain constant over time need only be shared once at the outset of the study. All customer-level data should be tagged by smart meter number. See the previous table for a schedule of the required prototype-specific data.

The Operator will share all data with CrossBoundary by uploading files to Odyssey.

(3) Site Economic Data

To assess the study's impact on mini-grid site economics, the Operator will share required site economic data for control and treatment sites. This data will be used to quantify the prototype's effects on Operator revenues, costs, and other important economic drivers.

Site economic data must be provided upon signing of the Operator Agreement, before disbursement of funds. The data should be shared by Operator's completion of the Excel table shown in *Annex 1*, which may be uploaded to Odyssey

(4) Survey Data

Surveys will be conducted to collect demographic, socioeconomic, and user experience data of study participants at control and treatment sites. Two surveys will be administered over the course of the study: (1) a baseline survey deployed prior to the prototype's launch and (2) an endline survey deployed following the prototype's end.

The surveys will measure asset ownership, current spending patterns, and current energy use patterns, among other metrics. This data will be analyzed to understand the prototype's impact on the socioeconomic status and well-being of participants.

The following table details the survey schedule for this prototype.

Survey	Audience	Format Administered
Baseline	Control and treatment sites, sample survey	Phone / In person
Endline	Control and treatment sites, sample survey	Phone / In person

CrossBoundary will deploy the surveys through Ipsos with funding from the Innovation Lab budget. The schedule, audience, and format of surveys may change given any updates to Lab funding or study needs (i.e. sample size).

Risks

The following table outlines the risks involved in the study.

Risk	Description	Probability	Mitigation
Reliability of appliances	Some mills have previously proved unable to mill African maize because African maize is purportedly hard and difficult to grind	Low	• Developers pre-test appliances in-country before deploying to customers • Work with suppliers to identify products best suited for mini-grid use and solve any performance issues related to appliances
Customer acceptance of appliance and quality of product	Customers are quite particular about products such as flour - the fineness is crucial for sales; millers also tend to prefer large diesel machines for faster throughput	Medium	• For mills: test appliances in-country with multiple sieve sizes to ensure flour is fine enough • For mills: Offer appliances under a discounted tariff structure to optimize the business case for millers

Risk	Description	Probability	Mitigation
Increasing mini-grid capital and operational expenditure	At sites where a diesel generator supplements solar generation, increasing consumption on the mini-grid could raise opex due to increased diesel consumption by the genset; large increases in consumption could require capex expansion	Medium	• Instate time-of-use tariffs for productive use appliances to incentivize daytime consumption, drawing power primarily from solar rather than batteries or genset • In the case daytime loads increase dramatically, set the genset to run during peak load
Increased frequency of inverter overload events	Mini-grid inverters can be tripped by high inrush current of motored loads, increasing the frequency of grid-wide outages	Low	• Research motor starters for mitigating the inrush current • Instate time-of-use tariffs to discourage usage from residential customer at times of peak demand

Analysis and Evaluation

Full analysis and evaluation of the study's results will be performed by the Study Partners.

Analysis

Study Partners will thoroughly evaluate each hypothesis against the metrics outlined in this Study Design, both periodically throughout the study and at the study's end. Partners will, additionally, monitor and analyze the prototype's effects on customer behavior as well as its social and economic impact on treatment communities.

CrossBoundary will analyze to what extent the prototype improves the mini-grid business model and quantify the benefit or cost to developers of incorporating the prototype into their standard operations. CrossBoundary will do this by applying observed changes in revenues and costs to its proprietary financial model. The resulting impact on project IRRs and cash flows will be evaluated under different scenarios. CrossBoundary will also assess the impact of the prototype on customers' wellbeing and economic opportunities. CrossBoundary will then recommend improvements to the prototype's design and implementation, to be incorporated into a later study or taken up directly by developers.

Dissemination of Results

Regularly throughout the study, CrossBoundary will publish a brief report, or *Innovation Insight*, capturing the study's results against each hypothesis in an anonymized and aggregated form. At the end of the study, CrossBoundary will publish a complete report capturing the study's final results as well as the Lab's recommendations on scaling, further testing, or discarding of the prototype. For each report, all developers involved in the Lab will be given time to review the report for completeness and accuracy ahead of the report being published. The reports will be made publicly available and shared with stakeholders engaged in CrossBoundary's work, including but not limited to mini-grid operators, donors, investors, and government agencies. Findings may also be disseminated through sector events, such as conferences and workshops. Other Study Partners may publish anonymized and aggregated study results in peer-reviewed academic journals.

Annex 1: Site Economic Data

Key Project Economic Data
LC = Local Currency

Instructions: Please complete all cells colored blue. Note some rows are optional.

Input	Unit	Name of Site 1	Name of Site 2	Name of Site 3	Name of Site 4	Name of Site 5
Mini-Grid Sizing						
Number of Connections	#					
PV Generating Capacity	kW_p					
Battery Inverter size *(optional)*	*kVA*					
PV Inverter Size *(optional)*	*kVA*					
Diesel Generator Set *(optional)*	*kVA*					
Battery Storage *(optional)*	*kWh*					
Battery Regular Depth of Discharge Limit *(optional)*	*%*					
Number poles *(optional)*	*Poles per site*					
Diesel Use *(optional)*	*litre/month*					
kWh Produced from Diesel *(optional)*	*kWh/month*					
Diesel Cost *(optional)*	*LC/litre diesel*					
Diesel Expenditure *(optional)*	*LC/month expenditure*					
Night time consumption as % of total consumption *(optional)*	*%*					
Total CapEx						
Project Development Cost	*LC*					
Generation CapEx	*LC*					
Distribution CapEx	*LC*					
Labour CapEx	*LC*					
Logistics CapEx	*LC*					
OpEx						
Annual OpEx (historical)	*LC /site/year*					
Annual OpEx (projected)	*LC /site/year*					
Revenue						
Average tariff	*LC /kWh*					
Average consumption	*kWh/month/customer*					
15-year Consumption Forecast	*kWh/month/customer*	*See table below*	*See table below*	*See table below*	*See table below*	*See table below*
15-year ARPU Forecast	*LC /month/customer*	*See table below*	*See table below*	*See table below*	*See table below*	*See table below*

Consumption and Revenue ForecastDevelopers may specify assumptions rather than a specific consumption/revenue forecast e.g. annual escalation of 5%
Note: You may specify assumptions rather than a specific consumption/revenue forecast (e.g. annual escalation of 5%)

Year	*Unit*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Average Monthly Consumption Per Customer	*kWh/ month /customer*															
Average Monthly Revenue Per Customer	*LC / month /customer*															
Implied Tariff	*LC/kWh*	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check	Automatic formula for sense check

Annex 2: Customer Wellbeing (Social Impact) Hypotheses

Hypothesis	Metric	Source
1. *Income generation & employment* **Customers at treatment sites will report an increase in income generation compared to customers at control sites, exhibiting:** **a. a 10% increase in the proportion of households operating businesses within the compound;** **b. a 10% increase in the proportion of households using electricity to generate income;** **c. a 10% increase in spending of disposable income;** **d. a 10% decrease in the proportion of households for whom subsistence farming or casual labor is the primary source of income, or who report they are unemployed.**	• Proportion of households operating businesses within the compound • Proportion of households using electricity to generate an income • Weekly airtime expenditure • Proportion of households who report that their primary source of income is subsistence farming, casual employment or that they are unemployed	• Lab survey data
2. *Education* **Customers at treatment sites will report an increase in education investment among school-age children compared to customers at control sites, with customers reporting:** **a. a 25% increase in the number of hours spent on school work per child in school;** **b. a 5% increase in expenditure on school fees;** **c. a 3% increase in the proportion of school-age children who regularly attend school.**	• Hours spent on schoolwork per child in school • School fee expenditure • Proportion of school-age children who regularly attend school	• Lab survey data
3. *Sources of energy* **Customers at treatment sites will switch away from unclean, unsafe, and expensive energy sources for household use compared to customers at control sites, with customers reporting a 10% reduction in expenditure on non-mini-grid energy sources.**	• Expenditure on non-mini-grid energy sources	• Lab survey data

Hypothesis	Metric	Source
4. *Customer well-being* **Customers at treatment sites will derive greater well-being from their mini-grid service, with customers reporting greater satisfaction with their mini-grid service compared to customers at control sites, and access to electricity as having a more positive effect on their life.**	• Customer-reported score on satisfaction with mini-grid service • Customer-reported score on impact of having electricity on life	• Lab survey data
5. *Health* **Customers at treatment sites will report fewer energy-related health complaints compared to customers at control sites, with:** **a. 10% fewer customers reporting any kerosene accidents in the household in the last year;** **b. 10% fewer customers reporting any respiratory illness in the household in the last year.**	• Proportion of households experiencing kerosene accidents • Proportion of households experiencing respiratory illnesses	• Lab survey data
6. *Female empowerment* **Customers at treatment sites will report an increase in female empowerment compared to households at control sites, with 5% more households at treatment sites reporting that a female household member is either fully or partly involved in decisions on household expenses.**	• Proportion of households where a female household member is fully or partly in household expenditure decisions	• Lab survey data
7. *Access to financial services* **Customers at treatment sites will report more access to financial services compared to customers at control sites, with 5% more households using financial services from formal institutions (commercial banks, SACCOs, MFIs, NGOs).**	• Proportion of customers who use financial services from formal institutions	• Lab survey data

Annex 3: Operator-Specific Information

Site Selection

The following sites have been selected for execution of the study with [developer] in [country].

Site	Study Purpose	Households	Current Connections	Additional Information
[Site name]	Control / Treatment			

More sites may be added to the study pending initial results and Lab budget.

Budget

The following budget has been agreed to for execution of the study with [developer] in [country].

Implementation Plan

The following implementation plan has been agreed to for execution of the study with [developer] in [country].

Technical Design

The following details the technical design of the study with [developer] in [country].

Pricing and Loan Terms

The Operator will offer financing for the appliances over an [XX]-month period, requiring a deposit of 20% of the appliance's cash price and with monthly installments based on a 2.55% monthly interest rate. The following table details the implied deposits and monthly installments.

Appliance	Cash Price	Deposit	Monthly Installment	Tenor
[Appliance type]				