



CROSSBOUNDARY



ACCELERATING ACCESS TO ENERGY

Study Design: Tariff Reduction
2020

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Executive Summary

This study tests whether customers choose to purchase more power from their local mini-grid when tariffs are reduced.

The primary objectives of the study are:

1. Determine what impact subsidizing tariffs has on (1) the economics of mini-grids, (2) mini-grid operators' customer base, and (3) customer wellbeing and satisfaction.
2. Better understand customers' willingness-to-pay for mini-grid power.
3. Quantify the subsidy required to make mini-grids financially sustainable, considering the subsidy itself and the increased revenue resulting from increased consumption.

The study targets customers of currently operating mini-grids in Africa. The study will be conducted on site(s) where the mini-grid tariff is reduced by a set percentage or amount that is both significant to customers and sufficient to ensure sustainability of the Operator. The reduced tariff will be offered to all current and potential customers at selected site(s).

The study will assess the impact of subsidizing mini-grid tariffs on three principal matters: (1) grid economics, (2) customer base, and (3) customer wellbeing and satisfaction. ARPU and average consumption per user, among other metrics, will be used to analyze the impact on grid economics. Customer base will be assessed by measuring total customers, and customer wellbeing and satisfaction will be evaluated through customer-reported income and satisfaction scores. 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 five-year period, beginning [date].

Study Partners

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

Partner	Role
Funder	<ul style="list-style-type: none"> • Provides funding • Offers strategic oversight for the study
CrossBoundary (CB)	<ul style="list-style-type: none"> • 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)	<ul style="list-style-type: none"> • Disburses and monitors funds provided to Operator • Supports analysis and communication of study results
Operator	<ul style="list-style-type: none"> • 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	<p>Academic institutions:</p> <ul style="list-style-type: none"> • Supports study design • Supports analysis and communication of study results <p>Third parties (as identified):</p> <ul style="list-style-type: none"> • 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, the unit economics must make sense. Importantly, mini-grid customers typically pay higher tariffs than main grid customers, whose tariffs are subsidized to mask the true cost of their connections. As a result, customers may be limited in the electricity and appliances they can afford to use on a daily basis. There must exist a solution that allows mini-grid developers to recoup the cost to connect a rural customer while enabling these customers to afford the electricity they need. This study seeks to establish that solution by answering the question: does reducing the tariff increase consumption so much so that the loss in unit price is offset, increasing developer revenue?

This study, therefore, seeks to:

1. Determine what impact subsidizing tariffs has on (1) the economics of mini-grids, (2) mini-grid operators' customer base, and (3) customer wellbeing and satisfaction.

2. Better understand customers' willingness-to-pay for mini-grid power.
3. Quantify the subsidy required to make mini-grids financially sustainable, considering the subsidy itself and the increased revenue resulting from increased consumption.

The study targets customers of currently operating mini-grids in Africa. The study will be conducted on site(s) where the mini-grid tariff is reduced by a set percentage or amount that is both significant to customers and sufficient to ensure sustainability of the Operator. The reduced tariff 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 tariffs have been subsidized; **control sites** are defined as sites where tariffs have not been subsidized.

Hypothesis	Metric	Source
<i>Grid Economics</i>		
1. A minimum average tariff, defined by the new reduced tariff, is required to maintain mini-grid economics and preserve project IRR.	• IRR	• Developer revenue, project economic data
2. ARPU at treatment sites, excluding revenues from subsidy payments, will return to pre-treatment levels by year three.	• ARPU	• Smart meters
3. The price elasticity of demand (defined as the change in quantity divided by the change in price) for mini-grid power will be relatively elastic by year five ($-\infty < E_d < -1$), meaning a reduction in tariff will drive a proportionally larger increase in consumption, thereby increasing revenues.	• Price elasticity of demand	• Smart meters
4. Historically low-user customers will exhibit the largest percentage increase in consumption at treatment sites.	• % change in average consumption per user, segmented by customer quartiles	• Smart meters

Hypothesis	Metric	Source
<i>Customer Base</i>		
5. The customer base at treatment sites will be 10% greater than at control sites after one year.	<ul style="list-style-type: none"> • # of connections 	<ul style="list-style-type: none"> • Developer data
<i>Customer Wellbeing & Satisfaction</i>		
6. Customers at treatment sites will report a 10% increase in spending and greater satisfaction with mini-grid service over customers at control sites after one year.	<ul style="list-style-type: none"> • Median of customer-reported incomes • Median of customer-reported mini-grid service satisfaction scores 	<ul style="list-style-type: none"> • Lab survey data

Site and Participant Selection

Treatment sites will be chosen according to where the Operator has current operations and adjusting the tariff structure 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

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

Participants are all households considered members of the community or village.

Duration

The study is expected to run five years, 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 one year and annually thereafter.

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

Prototype-Specific Design Decisions

The tariff at each treatment site will be subsidized by \$[XX]/kWh, from \$[XX]/kWh to \$[XX]/kWh.

This amount has been determined according to CrossBoundary's proprietary model to ensure grid NPV is preserved and the Operator's operational expenditure is covered. This avoids a situation where the Operator is forced to sharply increase the tariff following the study's end. Specifically, the principles for determining the reduced tariff are:

1. Customers should not be exposed to a significant increase in tariff after the subsidy expires.
2. The subsidy intervention will keep the Operator whole: the project's baseline NPV is preserved under any reasonable scenario, and is within a tolerable NPV loss under the worst case scenario.

CrossBoundary's proprietary model incorporates any additional planned investments in generation and storage as consumption grows, and forecasts consumption curves, investment costs, and expected returns with and without the subsidy. See *Annex 3* for Operator-specific plans to ensure the reduced tariff is sustained following the study's end.

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 regular installments every six months for the duration of the study or until total funding is disbursed, whichever occurs first. The amount of each installment will be determined by applying the agreed-upon tariff subsidy to every kWh sold during the prior six months.

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:

- Reducing and maintaining the tariff at the agreed-upon reduced rate
- Interfacing with government agencies such as the regulator and Rural Electrification Authority, as necessary
- Interfacing with the public utility, as necessary
- 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
(1) Remote Monitoring & Customer Data	Customer consumption	kWh	Twelve months' historical (<i>as available</i>), prior to disbursement of funds + monthly for duration of study
	Customer electricity payment	Local currency	Twelve months' historical (<i>as available</i>), 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	Total initial customers	#	Once, at outset of study
	Total customers	#	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	Three times, prior to the prototype's launch, at the end of year one, 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. Three surveys will be administered over the course of the study: (1) a baseline survey deployed prior to the prototype's launch, (2) a follow-up survey deployed one year following the prototype's launch, and (3) 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
Follow-up	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
Usage increase too great for mini-grid to sustain	Increased electricity demand puts pressure on the mini, requiring a system upgrade or expansion	High	<ul style="list-style-type: none"> • Ensure Operator agrees to expand grid if energy demand surpasses supply
Usage increase not as robust as modeled, requiring tariff increase after subsidy rolls off	If usage does not increase by 200% by year 5, the site will not have returned to prior financials, requiring a tariff increase to further increase revenues.	Medium	<ul style="list-style-type: none"> • Continue to monitor usage increases for duration of study and determine what subsidy increase would be required. Assess if IRRs at current level are acceptable.
Customers at unsubsidized sites become aware of subsidized tariff	Operator faces customer complaints or dissatisfaction at control site(s) or other nearby sites not receiving the subsidized tariff	Medium	<ul style="list-style-type: none"> • Work closely with Operator to design clear communication and customer care plans

Risk	Description	Probability	Mitigation
Total subsidy not sufficient to cover additional demand from new customers	Enough new customers sign up that the total subsidy amount is not sufficient to cover the additional increase in consumption	Medium	<ul style="list-style-type: none"> • Select sites that exhibit significant customer penetration so there is a limited number of potential new customers • Allocate a portion of the budget to cover additional expected 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				
15-year ARPU Forecast	LC /month/customer	See table below				

Consumption and Revenue Forecast Developers 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														

Annex 2: Customer Wellbeing (Social Impact) Hypotheses

Hypothesis	Metric	Source
<p>1. <i>Income generation & employment</i> Customers at treatment sites will report an increase in income generation compared to customers at control sites, exhibiting:</p> <ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • Lab survey data
<p>2. <i>Education</i> Customers at treatment sites will report an increase in education investment among school-age children compared to customers at control sites, with customers reporting:</p> <ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> • Hours spent on schoolwork per child in school • School fee expenditure • Proportion of school-age children who regularly attend school 	<ul style="list-style-type: none"> • Lab survey data
<p>3. <i>Sources of energy</i> 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.</p>	<ul style="list-style-type: none"> • Expenditure on non-mini-grid energy sources 	<ul style="list-style-type: none"> • Lab survey data

Hypothesis	Metric	Source
<p>4. <i>Customer well-being</i> 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.</p>	<ul style="list-style-type: none"> • Customer-reported score on satisfaction with mini-grid service • Customer-reported score on impact of having electricity on life 	<ul style="list-style-type: none"> • Lab survey data
<p>5. <i>Health</i> 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.</p>	<ul style="list-style-type: none"> • Proportion of households experiencing kerosene accidents • Proportion of households experiencing respiratory illnesses 	<ul style="list-style-type: none"> • Lab survey data
<p>6. <i>Female empowerment</i> 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.</p>	<ul style="list-style-type: none"> • Proportion of households where a female household member is fully or partly in household expenditure decisions 	<ul style="list-style-type: none"> • Lab survey data
<p>7. <i>Access to financial services</i> 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).</p>	<ul style="list-style-type: none"> • Proportion of customers who use financial services from formal institutions 	<ul style="list-style-type: none"> • 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.

Prototype-Specific Design Decisions

To ensure the reduced tariff is sustained following the study's end, [developer] commits to modularly adding solar and storage capacity to treatment site generating unit(s) as needed. This will keep diesel consumption manageable despite increased consumption.

Budget

The following budget has been agreed to for execution of the study with [developer] in [country]. The agreed-upon tariff subsidy is \$[XX]/kWh.

Implementation Plan

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