CROSSBOUNDARY

Study Design: Metering

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Executive Summary

The study will compare multiple metering systems across a set of parameters to advise on the performance differences among meters and support mini-grid developers in making more informed decisions when purchasing meters in bulk. The study will allow for a comprehensive description of smart metering technologies to aid mini-grid developers in selecting the most efficient technologies given specific site conditions.

The primary objective of the study is:

1. Benchmark the performance of five smart metering technologies as pertains to hardware and software systems to optimize unit economics for mini-grid operators.

The study will be conducted in two types of environments: (1) currently operating mini-grid sites in Africa where the Operator installs new meters in participant households but otherwise follows standard operations (defined as **field sites**); (2) university labs in East Africa where Carnegie Mellon University performs tests in a controlled setting (defined as **lab sites**).

The study will assess the impact of six different smart metering technologies on thirteen parameters that directly impact the mini-grid business model: (1) cellular signal, (2) range, (3) resilience to interference, (4) power consumption, (5) anti-tampering capabilities, (6) failure rate, (7) uptime, (8) cost, (9) size, (10) system complexity, (11) top up time, (12) API availability, and (13) data consumption. Each will be assessed by measuring specific metrics as outlined in this Study Design.

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 • Disburses and monitors funds provided to Operator • Leads data collection, including surveying, and data cleaning • Leads 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 identifying the most efficient and cost-effective smart metering technologies for mini-grid operators to employ given a range of site conditions.

Meters play an essential role in any power provider's business model. Optimal meter selection directly impacts grid-level economics in three distinct ways:

1. Reduces O&M costs via reduced site visits
2. Ensures the most efficient allocation of capital expenditure
3. Increases revenue via improved customer satisfaction

A plethora of meters, varying in cost and technical capabilities, are currently available to mini-grid operators. However, just two technologies dominate the sector and are often the only systems developers trust given the lack of information on competitors. Perhaps more consequential, these leading technologies are still quite young.

The smart meter mini-grid sector is overwhelmed by startups, but mini-grid developers are increasingly needing industrial quality solutions to operate successfully at scale. For the smart metering sector to mature into the commoditized, industrial quality equipment that developers benefit from with PV panels, inverters, and batteries, there must be more competition from more diverse companies. There must be competition, for instance, from companies with industrial scale manufacturing facilities, with millions of meters deployed and enterprise-grade software.

Smart meters represent 30-40% of a developer's operating costs, making it critically important developers are able to make fully informed decisions on meter selection. The only way for mini-grid developers to consider a new meter vendor at scale is through field pilots, yet no single developer has the time or resources required to conduct a comprehensive field trial with multiple vendors, across multiple sites, producing rigorously-tested and reliable results.

This study, therefore, seeks to:

1. Benchmark the performance of five smart metering technologies as pertains to hardware and software systems to optimize unit economics for mini-grid operators.

The study will be conducted in two types of environments: (1) currently operating mini-grid sites in Africa where the Operator installs new meters in participant households but otherwise follows standard operations (defined as **field sites**); (2) university labs in East Africa where Carnegie Mellon University performs tests in a controlled setting (defined as **lab sites**).

Experimental Design

Test Parameters

Meters will be evaluated across thirteen test parameters that measure performance of the meters' hardware and software systems. The following table details the parameters the study will test and how each will be measured.

Parameter ***(Impact on Business Model)***	**Metric**	**Site**	**Source**
Hardware System **1. Cellular signal** *(impacts revenue, as a stronger signal results in greater uptime)*	• Network strength at site (decibels)	• Field, Lab	• Signal strength meter

Parameter *(Impact on Business Model)*	Metric	Site	Source
2. Range *(impacts cost, as a limited range increases the number of meters required to operate a site)*	• Radius of signal (km)	• Field	• Spectrum analyzer
3. Resilience to interference *(impacts revenue, as interference lowers uptime)*	• % of packets lost on pinging meter per month (%)	• Field, Lab	• Spectrum analyzer
4. Power consumption *(impacts revenue, as consumption is a principal source of revenue)*	• Power meter needs to operate (kWh) • Average monthly consumption per user (kWh) • Median monthly consumption per user (kWh)	• Field (metrics 2 and 3), Lab (metric 1)	• Multimeter
5. Anti-tampering capabilities *(impacts revenue, as poor anti-tampering functionality increases the likelihood of power theft)*	• # of power theft incidents detected per year (#)	• Field	• Developer measurements from test results
6. Failure rate *(impacts cost, as a greater failure rate increases the number of meter replacements required)*	• # of times meter fails per year (#)	• Field	• Developer measurements from test results
7. Uptime *(impacts revenue, as power consumed during downtime is lost revenue)*	• Uptime % per month (%)	• Field	• Developer measurements from test results

Parameter *(Impact on Business Model)*	Metric	Site	Source
8. Cost *(direct measure of cost)*	• Total capital expenditure ($) • Monthly operational expenditure ($)	• Field	• Developer data
9. Size *(impacts cost, as larger meters are more expensive to operate)*	• Surface area of meter (sq cm)	• Lab	• Developer measurements from test results
10. System complexity *(impacts cost, as more components increase the likelihood of meter failure)*	• # of separate components of meter system (#)	• Lab	• Developer measurements from test results
Software System			
11. Top up time *(impacts revenue, as long top up times can discourage customers from purchasing power)*	• Average time required to top up (sec) • Median time required to top up (sec)	• Field, Lab	• Developer measurements from test results
12. API availability *(impacts cost, as limited API functionality increases the effort required to collect and analyze data)*	• # of set list of APIs to which meter can connect (#)	• Field, Lab	• Developer measurements from test results
13. Data consumption *(impacts cost, as more data increases operating costs)*	• Average monthly data consumption per user (KB) • Median monthly data consumption per user (KB)	• Field	• Developer measurements from test results

See *Annex 3* for detailed test methodology on each parameter.

Site and Participant Selection

Field sites will be chosen according to where the Operator has current operations. All sites are eligible to serve as field sites; however, priority will be given to those sites meeting the following criteria:

- At least 100 customers
- At least six months of customer consumption data
- Capability to automatically measure customer consumption
- Together represent a diversity of location types (i.e. rural and semi-urban), climate, topography, and network conditions

Lab sites will be chosen according to where Carnegie Mellon University has current lab operations.

Field site participants are those households representing some minimum contiguous section of the community or village of which they are members who have been selected for the study. Study Partners will select participants on a site by site basis to account for topography and other site-specific factors.

See *Annex 2* for Operator-specific site and participant selection information.

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].

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

Prototype-Specific Design Decisions

Meters to be evaluated were selected by a community of East African operators interested in deploying this study. Priority was given to those meters not previously tested or currently used on a large scale in the region. The following meters were chosen for evaluation:

- Elmeasure
- Hexing
- Shenzhen Calinmeter
- Sparkmeter
- SteamaCo

The meters tested may change in response to any changes to Lab funding, study needs, or feasibility of procurement.

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 2* 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 CrossBoundary 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 CrossBoundary. The Operator agrees to use funds solely for the purposes of the study.

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

Implementation

Operator

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

- Procuring new meters for field sites
- Installing and maintaining new meters in the homes of all participants on field sites
- 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 2* 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).

Carnegie Mellon University

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

- Procuring and readying all equipment needed on lab sites

Carnegie Mellon University will support the Operator in engaging all third parties involved in the study.

Carnegie Mellon University agrees to inform CrossBoundary of any occurrences that may affect study results.

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 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. No surveys will be conducted for this study. 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	Monthly for duration of study
	Customer electricity payment	Local currency	Monthly for duration of study
	Meter numbers with customer information	Various	Once, prior to disbursement of funds
(2) Prototype-Specific Data	Network strength at site	Decibels	Quarterly for duration of study

Data Type	Metric	Unit	Frequency
	Radius of signal	km	Quarterly for duration of study
	% of packets lost on pinging meter per month	%	Quarterly for duration of study
	Power meter needs to operate	kWh	Quarterly for duration of study
	# of power theft incidents detected per year	#	Quarterly for duration of study
	# of times meter fails per year	#	Quarterly for duration of study
	Uptime % per month	%	Quarterly for duration of study
	Total capital expenditure	$	Quarterly for duration of study
	Monthly operational expenditure	$	Quarterly for duration of study
	Surface area of meter	sq cm	Once, at outset of study
	# of separate components of meter system	#	Once, at outset of study
	Average time required to top up	sec	Quarterly for duration of study
	Median time required to top up	sec	Quarterly for duration of study
	# of set list of APIs to which meter can connect	#	Once, at outset of study
	Average monthly data consumption per user	KB	Quarterly for duration of study
	Median monthly data consumption per user	KB	Quarterly for duration of study
(3) Site Economic Data	**As shown in *Annex 1***	Various	Once, prior to disbursement of funds

(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.

Risks

The following table outlines the risks involved in the study.

Risk	Description	Probability	Mitigation
Logistics Risk	Delayed procurement of meters and high transport (shipping & road) costs	High	• Use reliable suppliers
Vendor resistance to study	Vendors may be resistant to their devices being used for the study	High	• Interface with vendors through CrossBoundary
Significance of results	Working with a few meter samples from each vendor could limit the accuracy of results	Medium	• Clearly account for this in report
Technical Risk	Failure of meters in field that affecting customer electricity supply	Medium	• Incorporate meter isolation circuits
Operational risk	Customers resistant to addition of meters to their homes	Medium	• Interface with customers through the developer customer engagement teams

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 then recommend improvements to the prototype's design and implementation, to be incorporated into a later study or taken up directly by developers.

CMU will assess all metering technologies against the agreed upon parameters, testing each as outlined in this study design. The results of these tests will be used to inform recommendations on optimal metering technologies across a range of conditions.

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.

CMU will publish an unbiased assessment of available metering technologies, made publicly available through a sector-wide report or academic paper. The report will offer recommendations on optimal metering technologies dependent on several factors: location (rural, semi-urban), climate, topography, and available network infrastructure. Additionally, CMU will create a multi criteria decision tool designed to suggest appropriate meters given certain site characteristics. The report and tool will serve as a guide for developers on the capabilities and technical performance of commercially available technologies, allowing developers to select those technologies best suited for their site conditions and systems.

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: 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].

Annex 3: Test Procedures

Setup

In the field, meters will be connected in series at all households included in the study. To ensure testing of these metering technologies doesn't impact the Operator's existing metering system, bypass circuits will be designed to isolate test meters as needed.

In the lab, meters will be set up in a way that can easily be replicated across various mini-grid sites.

Testing Devices

The study will employ the use of the following testing devices:

1. Signal spectrum analyzer *(Field)*
2. Handheld spectrum analyzer *(Lab)*
3. Signal strength meter *(Field, Lab)*
4. Cell boosters *(Field)*
5. Directional antennas *(Field, Lab)*

Hardware System Test Procedures

1. Cellular signal (Field, Lab)

Purpose
Identify the meter's signal strength from the nearest base stations.

Equipment and Materials

- Signal Strength meter
- OpenSignal android/iOS Application
- Network Operator SIM cards

Procedure

1. Identify all operators providing service in the area
   Download free Application OpenSignal available both on Google Play and App Store. Use app to identify available operators in location.

2. Measure signal strength of each available operator
   Input operators SIM card into signal strength meter and measure signal strength in decibels. Record results.

3. Note download and upload speeds
   Record download and upload speeds using OpenSignal App.

2. Range (Field)

Purpose
Determine the maximum range of operation of the meter.

Equipment and Materials
- Spectrum Analyzer

Procedure
1. Select positions to install DCU and smart meters
   The DCU should be located at a central point within the selected site. The households selected should be at varying distances from the DCU.

2. Connect meters to households
   The smart meters should be installed at each selected household and communication established between each meter and the DCU.

3. Measure signal strength from the DCU to each meter
   Control signals can be sent from the DCU to each meter and a Spectrum Analyzer used to measure the strength of each signal received.

4. Record the signal strength at each meter.
   Record the distance of the meter from the DCU, the surrounding environment (trees, buildings, etc.), frequency of transmission, transmit power, and antenna gain. This information will be used to determine the range of coverage for each meter type.

3. Resilience to interference (Field, Lab)

Purpose
Determine the extent to which induced interference affects meter performance.

Equipment and Materials
- Signal Generator
- Spectrum Analyzer

Lab Procedure
1. Determine frequencies of operation of selected meters
   Consult manufacturer datasheets, speak with technical support teams, or use a Spectrum Analyzer during meter operation to identify the specific frequencies with which the meter can communicate.

2. Simulate interference signals
   Using a signal generator, generate interference signals at the same frequencies as those of the meter.

3. Record meter performance
   Record how meter performance is affected by interference and determine meter resilience to meter interference.

4. Power consumption (Lab)

Purpose
Determine the power consumption recorded by the meter.

Equipment and Materials
- Multimeter
- Load such as a bulb
- Cable
- Electrical Plug

Lab Procedure
1. Create a closed electrical circuit with the meter and load as only loads
   Connect meter and bulb in series in an electrical circuit. Use socket outlet as a voltage source.

2. Measure voltage and current across the meter
   Measure and record voltage and current across the meter and use these values to determine the meter's power consumption. Record consumption for each meter.

5. Anti-tampering capabilities (Field)

Purpose
Determine the effectiveness of meter anti-tampering technology.

Equipment and Materials
- Cables
- Pliers
- Screw drivers

Procedure
1. Contact local technical professionals
   Identify local talent at each site with an electrical technical background.

2. By pass meter tests
   Allow the technicians to independently attempt to bypass the meters without being detected by the meter's anti-tampering features.

3. Record results

Record all successful and unsuccessful attempts. For successful attempts, record the anti-tampering feature that failed to detect the bypass attempt and the technician's level of expertise.

6. Failure rate (Field)

Purpose
Determine how often the meter is prone to failure.

Equipment and Materials
- *None*

Procedure
1. Record how many meters are connected at the site from each vendor
   Note each meter connected in series at each selected household.

2. Record each meter that fails
   Record any meter failure and the root cause of that failure. Note whether failure required intervention from the vendor, replacement of the meter by the vendor, or support from the maintenance team on the ground.

7. Uptime (Field)

Purpose
Determine the percentage of time the metering system is offline.

Equipment and Materials
- *None*

Procedure
1. Retrieve connectivity data sent from smart meters
   Obtain connectivity data from the meter vendor either by requesting it directly or searching for it on the software platform.

2. Write script to calculate uptime per month
   Create an excel or python script to calculate the uptime per month for each metering system using data obtained from the vendor.

8. Cost (Field)

Purpose
Determine the total cost required to operate the meter.

Equipment and Materials
- *None*

Procedure

1. Identify the total capital expenditure involved in setting up the meter
   Record the total cost of setting up the meter, including the cost of the meter itself.

2. Identify the average monthly operational expenditure involved in operating the meter
   Track the monthly expenditure involved in operating the meter, including any maintenance costs. Regularly average the data as available.

9. Size (Lab)

Purpose

Determine the total surface area of the meter.

Equipment and Materials

- Ruler

Procedure

1. Measure the length (L), width (W), and height (H) of the meter
   Use a ruler to measure the length, width, and height of the meter.

2. Calculate the surface area (S) of the meter
   *Use the following formula to calculate the surface area of the meter: Surface Area (S) = 2(L*W) + 2(L*H) + 2(H*W).*
   NB: Meter shape assumed to be near square or rectangular prism.

10. System complexity (Lab)

Purpose

Determine the number of separate entities needed for the metering system to function.

Equipment and Materials

- *None*

Procedure

1. Count the individual components needed for the system to function
   Count the number of independent components that must be connected for the system to function. Every piece should be counted, including servers, antennas, modem, and cables.

Software System Test Procedures

11. Top up time (Field, Lab)

Purpose

Determine how long it takes to credit a meter once a payment is made.

Equipment and Materials

- *None*

Procedure (Field)

1. Top up meter
   Follow procedure as described by meter vendor to make meter payment using online meter platform. Record timestamp when payment is made.

2. Note timestamp when top up is made
   Access meter using optical or USB port (depending on meter design) and read the timestamp indicating when the top up was made. If the meter is inaccessible, use a watch to determine the timestamp.

3. Calculate top up delay
   Determine the top up delay by calculating the difference between the timestamp indicating the payment was made and the timestamp indicating the meter was topped up.

Procedure (Lab)

1. Retrieve payment and meter credit data
   Obtain payment and meter credit data from the meter vendor's online platform.

2. Write script to calculate top up delay
   Create an excel or python script to calculate the top up time delays realized for each customer transaction.

12. API availability (Field, Lab)

Purpose

Determine the meter's ability to connect to established APIs.

Equipment and Materials

- *None*

Procedure

1. Identify the APIs to which the metering system is able to connect
   Note each distinct API to which the metering system has the capability to connect. Sum the total.

13. Data consumption (Field)

Purpose

Determine the data required for the metering system to operate.

Equipment and Materials

- *None*

Procedure

1. Determine the rate at which data is used by the system
   Use performance or payment data to calculate the metering system's data consumption rates.