Global Energy Alliance for People and Planet
GEAPP

CrossBoundary Group

Innovation Insight

Harmonizing tariffs through smart green subsidies in Sierra Leone

Final report

Image: © Tinkonko site


Image: © Adebayo Community

Glossary

Abbreviation	Full Name
ACPU	Average Consumption Per User
ARPU	Average Revenue Per User
BAU	Business As Usual
CAGR	Compound Annual Growth Rate
CapEx	Capital Expenditure
CPI	Consumer Price Index
EWRC	Electricity and Water Regulatory Commission
FCDO	Foreign, Commonwealth and Development Office
GEAPP	Global Energy Alliance for People and Planet
IRR	Internal Rate of Return
kWh	Kilowatt Hour
kWp	Kilowatt Peak
(N)	Nominal Values

Abbreviation	Full Name
(R)	Real Values
RBF	Results Based Financing
SEforALL	Sustainable Energy for All
SLE/SLL	Sierra Leonean Leone, currency of Sierra Leone
UEF	Universal Energy Facility
UNOPS	The United Nations Office for Project Services
US$	United States Dollar
WACC	Weighted Average Cost of Capital
WP1	Work Package 1 sites implemented by the government in partnership with UNOPS and funded by FCDO to enhance energy access in Sierra Leone.
WP2	Work Package 2 represents sites implemented by the government in partnership with UNOPS and funded by FCDO to enhance energy access in Sierra Leone.

The 12-month tariff harmonization pilot has proven successful, tackling affordability challenges and boosting minigrid utilization.

The Lab, in partnership with Global Energy Alliance for People and Planet (GEAPP) and the Government of Sierra Leone, launched a 1-year Tariff Harmonization Pilot across Sierra Leone in December 2022, to test the impact of lower tariffs on customers.

The tariff was cut from SLE 7.527 (US$0.58) to SLE 4.439 (US$0.34), resulting in an average 41% tariff reduction across 8 treatment sites.[1]

1. NOTE: The Energy and Water Regulatory Commission (EWRC) recommended tariffs for WP1 and WP2 sites range from SLE 6,100 to SLE 8,000. Developers implemented varied rates within this range. For this study, we used SLE 7.527, the average cost-reflective tariff at the start of the study

After the 12-month pilot period, the results effectively demonstrate that reducing tariffs increases energy consumption, especially for low-income customers, sufficiently to offset revenue impacts. Key insights from the pilot close-out analysis include:

Reduced tariffs and high reliability result in significant increases in consumption. Lower tariffs have led to a 58% average increase in Average Consumption Per User (ACPU) on treatment sites, compared to a 6% increase on control sites. For sites with >40% reliability, treatment sites showed an even higher ACPU growth of 64%.

Site utilization has increased by 8 pp since pilot launch from 32.9% to 40.9% on treatment sites, while utilization has remained constant on control sites over the same time frame (39.6%).

The lowest consuming users, often from the lowest income segments (including casual laborers and subsistence farmers), benefit the most from tariff reduction. Tier 0-1 constitutes 63% of customers across sites and their ACPU has increased by 46% on treatment sites compared to just 5% on control sites. Though these customer are still relatively low consumers (~4kWh per month) their cumulative impact on overall consumption is significant.

Customers have expressed satisfaction with their electricity connections and have responded positively to tariff reduction by demanding more appliances, increasing business productivity and engaging in new social welfare programs.

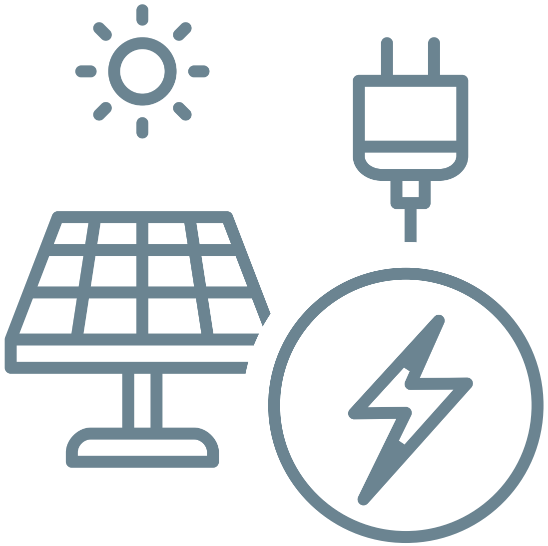
Developers can lower tariffs and increase revenues in local currency, but this may not hold true in hard currency or when taking into account inflationary impacts. The Average Revenue Per User (ARPU) at treatment sites increased by 10% in SLE compared to a 4% increase at control sites. However, in real value, ARPU in both local currency and US$ has decreased by more than 30%.

This means that though tariff reduction works and could be implemented at scale, interventions are needed to achieve sustainability

Macroeconomic challenges in Sierra Leone including rising inflation and a weakening local currency have impeded potential scale-up plans. Even though the effective tariff across sites has remained at SLE 7.527, its dollar equivalent declined substantially to $0.34 during the pilot period. This translates to a 21% reduction in dollar terms, which means that the effective tariff has also undergone a tariff reduction. The unchanged tariff in local currency terms has made energy relatively more affordable for consumers but has posed operational sustainability challenges for developers.

The results lead us to conclude that tariff reduction works and could be implemented at scale – however a suite of interventions is required to make mini-grids investable, sustainable and affordable for consumers.

These interventions include a streamlined, efficient subsidy regime to maximize tariff reduction potential. They could also include hedging mechanisms to safeguard minigrid businesses against macroeconomic shocks. As a next step, CrossBoundary Innovation Lab will work with partners to leverage this analysis as well as findings from other subsidy programs to define an optimized subsidy regime and supporting mechanisms.



Context: The lab leveraged lessons from tariff reduction prototypes in Tanzania to trial out a nationwide tariff harmonization pilot in Sierra Leone.

01 Overview of Tariff Harmonization through subsidies

- The Lab's 2018 tariff reduction prototype in Tanzania showed that **reducing tariffs by 50-75%** increased electricity consumption by 1.5-3x baseline levels after two years
- In December 2022. the Lab launched a similar prototype in Sierra Leone with the aim of reducing tariffs by up to 60% across 100 sites from the average tariff of US$ 0.58 (SLE 7.527), starting with a **pilot across 8 treatment sites and 9 control sites**
- The **subsidized tariff** was determined through a combination of elasticity modeling, a tariff "floor" to cover developer operational and maintenance costs, and considerations for subsidy sustainability
- The subsidized tariff was set at **SLE 4.439** (US$ 0.46/kWh) at the time of project design but equivalent to **USD$ 0.34/kWh** at the time of pilot kick-off, following a devaluation
- The subsidy paid per developer was the **delta between the base tariff and the subsidized tariff** to make the developer sum whole (see appendix for further subsidy calculation information)
- To participate, the developers entered into a Service Level Agreement (SLA) with CrossBoundary agreeing to **adhere to the following standards:**
  - Maintaining **tariff at treatment sites at SLE 4.439** and at control sites at SLE 7.527 throughout the pilot
  - Maintaining **system uptime of at least 80%** over the pilot period, where uptime was defined by the percentage of time the grid provided stable electricity supply to consumers

02 Key ingoing hypotheses

- ACPU will increase by >40% from baseline levels as a result of reducing the tariff
- Price elasticity of demand will be >0.8 at ~SLE 4.439/kWh
- Site capacity utilization will increase by 40% within 12 months of reducing the tariff

Partners

Developers

All developers operating in Sierra Leone participated in the pilot: Energicity, PowerGen, and WINCH (NOA Leone)

Sierra Leone Government Agencies

- Ministry of Energy
- Electricity and Water Regulatory Commission (EWRC))

Funders

Technical Partners

Mini-grids in Sierra Leone were developed under the Government of Sierra Leone's Rural Renewable Energy Project (RREP) supported by UNOPS and funded by FCDO under two work packages and across four lots.

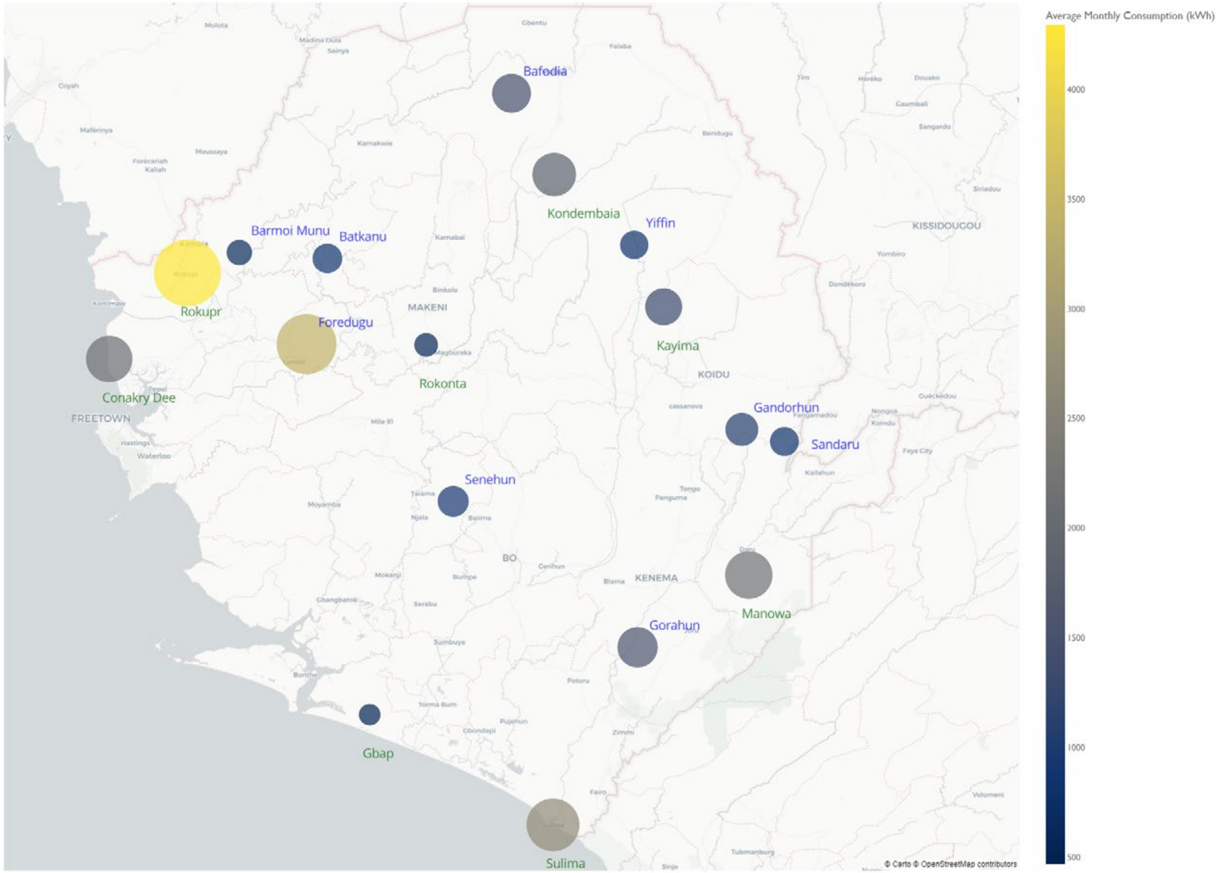
Work Package 1 (WP 1) sites involved installing 16-36 kWp solar generation systems in 50 community health centers across 14 districts. Work Package 2 (WP2) involved working with the three private companies operating minigrids installed under WP1 to electrify 44 additional rural communities. The three companies coinvested in building 36 kWp to 200 kWp minigrids through public-private partnerships with the Ministry of Energy.

The Lab selected 8 treatment sites from these mini-grids according to the following criteria

- 2 sites per Lot (WP1 and WP2)
- Geographic distribution
- Available capacity

Context: 3300+ customers were impacted across multiple locations in Sierra Leone during the tariff reduction pilot

Pilot site locations showing average monthly consumption and number of connections (Kilowatt Hour (kWh))



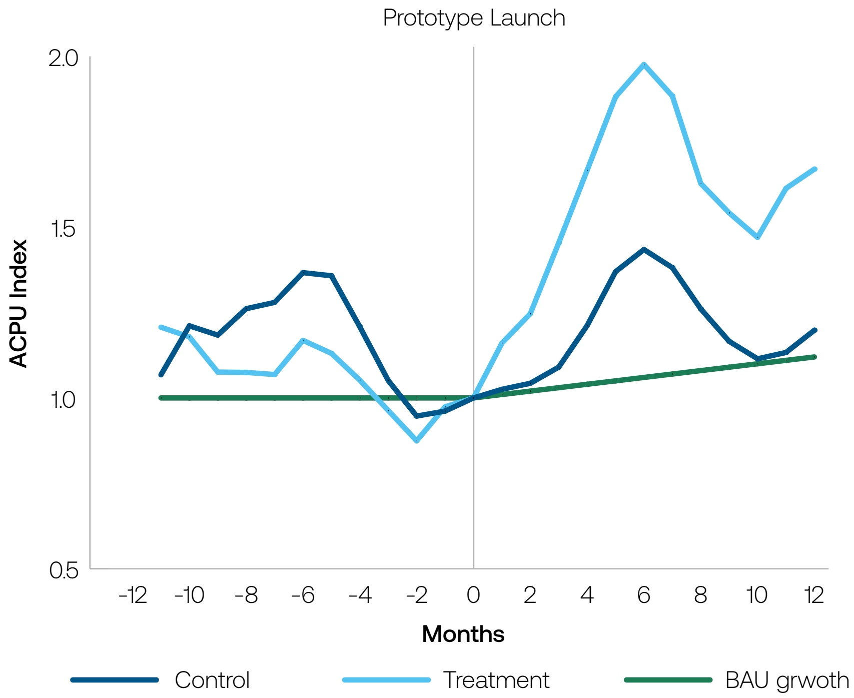
1. SEforAll, Government of Sierra Leone, UNOPS, Developers

01

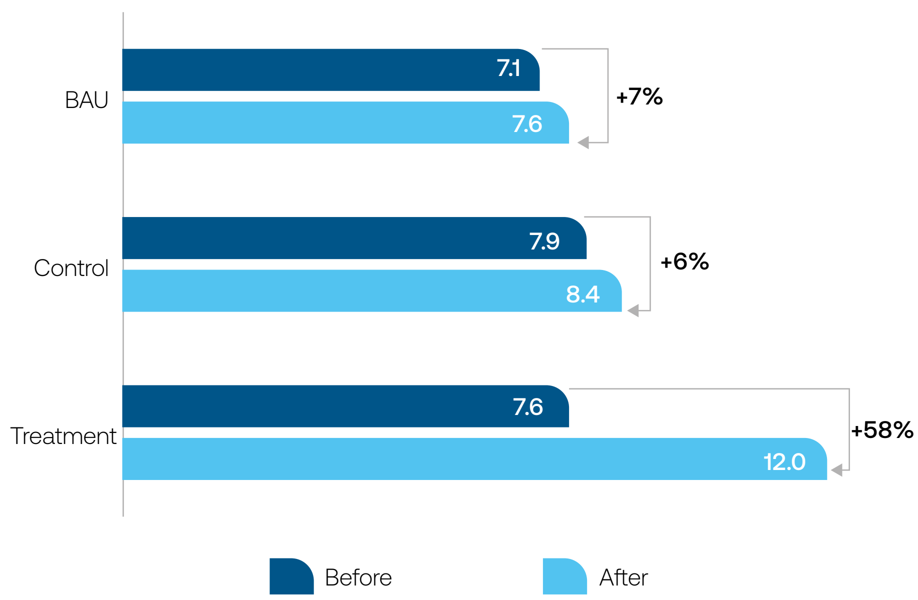
Reduced tariffs and high reliability result in significant increases in consumption.

ACPU has increased by an average of 58% on treatment sites compared to a 6% increase on control sites

ACPU profile over 12-month pilot period (#)



Average ACPU over 12-month pilot period (kWh/month)



The averages shown on the ACPU index are 3-month moving averages. The averages are computed at the site level rather than the consumer individual meter level considering contextual differences across sites

ACPU index is calculated by dividing the average consumption at any month by the average at month 0

Before = Months -11 to 0; After = Months 0 to 11

BAU = Business As Usual. BAU is modelled to begin at an average ACPU of 7.1 kWh/month and is modelled to grow at 12% p.a.

What we're seeing

Over the course of the pilot, treatment sites experienced a **58% ACPU increase**, compared to a **6% ACPU increase** at the control sites.

The graphs show energy consumption data from all treatment sites across all developers (see appendix for disaggregated site consumption). The data covers the pilot period (months 0 to 11) and one year prior to the pilot's commencement (months -11 to 0). Developer 1 sites had significantly higher consumption than other developers, attributable to the developers' optimized operational model.

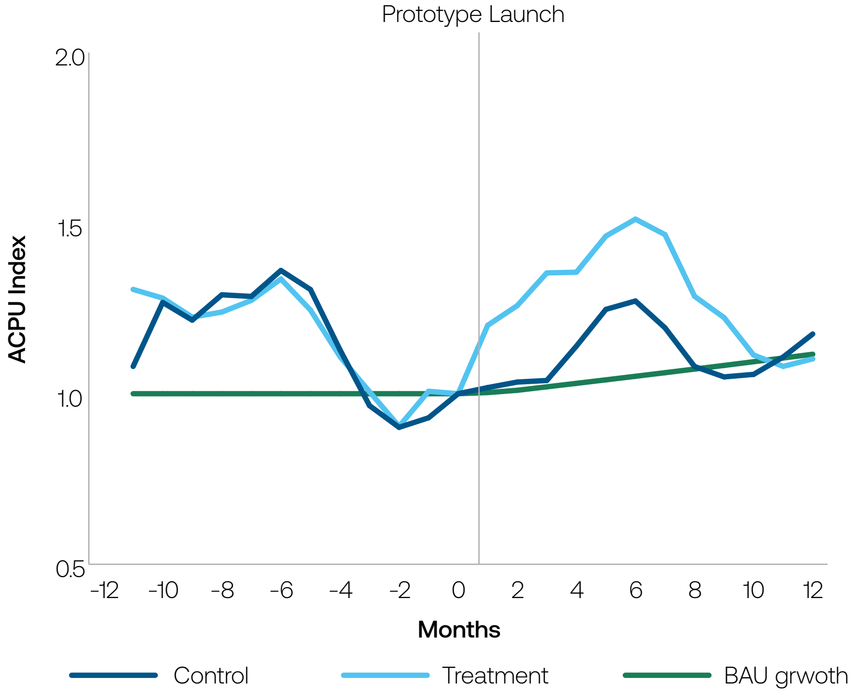
The consumption profile shows seasonal impacts **including a spike in month 6 indicating the peak during harvest across both treatment and control sites**. ACPU decreases following this spike and further reduces due to technical issues arising at some sites, including low uptime from damaged network poles, faulty batteries, and generator downtime.

What it means

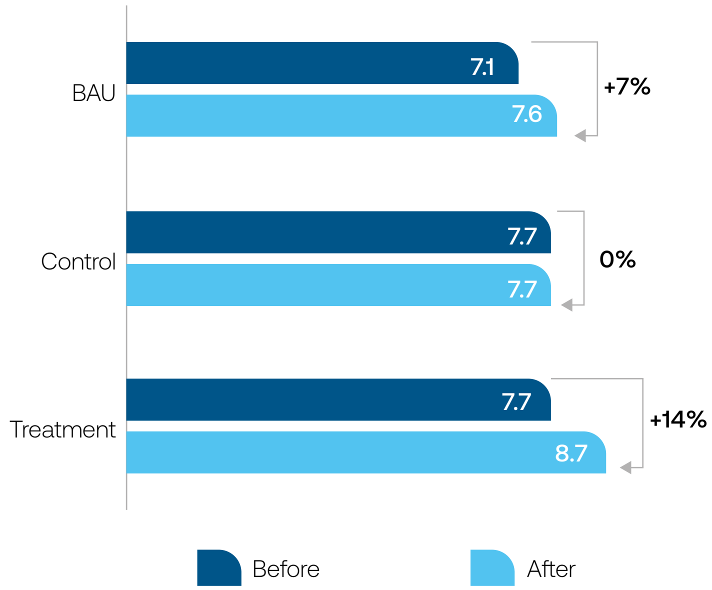
Tariff reduction works – treatment sites have experienced an ACPU growth of 52% more than the control sites and 51% more than the ACPU growth under BAU scenario.

Excluding developer 1 sites to eliminate outlier impact, average ACPU growth on treatment sites increases by 14%

ACPU index profile over 12-month pilot period (#)



Average ACPU over 12-month pilot period (kWh/month)



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Before = Months -11 to 0; After = Months 0 to 11

BAU = Business As Usual. BAU is modelled to begin at an average ACPU of 7.1 kWh/month and is modelled to grow at 12% p.a.

What we're seeing

After excluding Developer 1 sites, **treatment sites have experienced an ACPU growth of 14%.** Control sites have not experienced any growth over the same period.

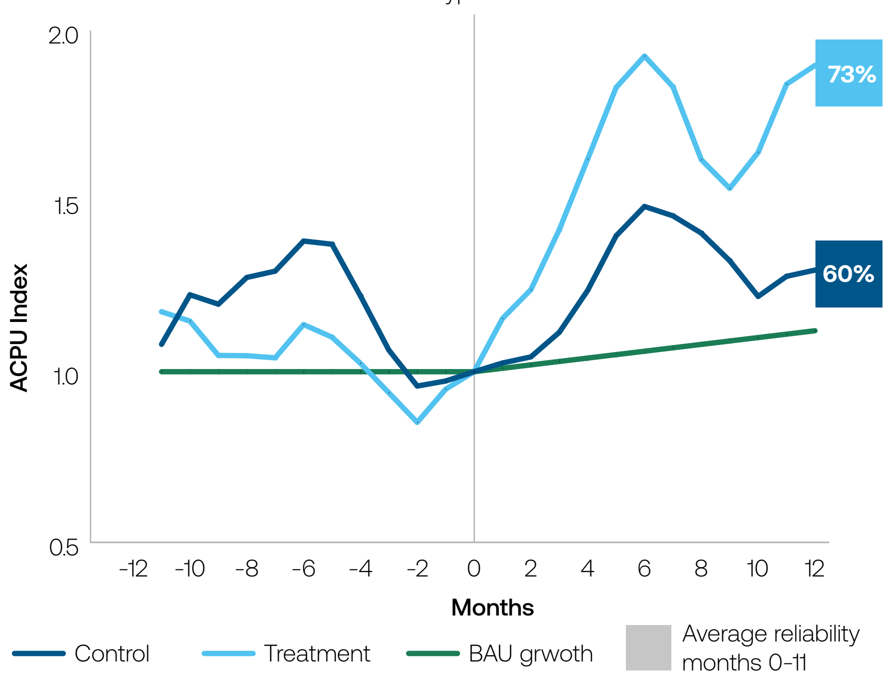
What it means

Tariff reduction works even when developers are not operating as efficiently and optimally as they could be.

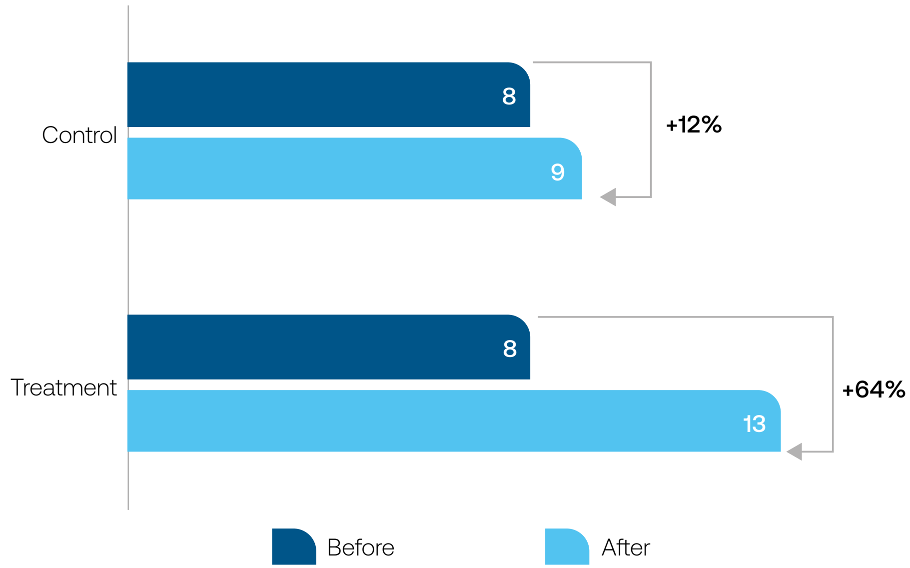
However, **developers and consumers benefit more from tariff reduction if grids are operated efficiently and with higher reliability.** Factors such as faulty battery equipment and generators led to partial or full shutdowns at these sites, reducing potential gains. The impact of site reliability is further detailed later in this report.

Higher reliability results in increased consumption – even when tariff reduction is not applied

ACPU index profile over 12-month pilot period, filtering sites with reliability above 40% (#)



Average ACPU over 12-month pilot period, filtering sites with reliability above 40% (kWh/month)



The averages shown on the ACPU index are 3-month moving averages. The averages are computed at the site level rather than the consumer individual meter level considering contextual differences across sites
ACPU index is calculated by dividing the average consumption at any month by the average at month 0
Before = Months -11 to 0; After = Months 0 to 11

What we're seeing

Reliability (or uptime) is defined here as the percentage of time the grid provided stable electricity supply to consumers.

Developers struggled to meet reliability targets of at least 80% across most sites, especially after month 6 of the trial. The period marked the onset of the impact of macroeconomic challenges, various technical issues, including battery replacements, poor internet connectivity affecting uptime data recording, generator failures, fuel shortages, and maintenance delays.

A minimum reliability threshold of 40% was applied considering these challenges. After filtering to include reliability above this threshold, **treatment sites showed an ACPU growth of 64% compared to 58% increase prior to filtering.** The control sites show growth of 12% over the same period compared to 6% increase prior to filtering.

Note: All treatment sites maintained an average reliability above 58%. Four sites experienced reliability below 40% for three months due to system faults, including generator issues, battery maintenance, and MV line problems.

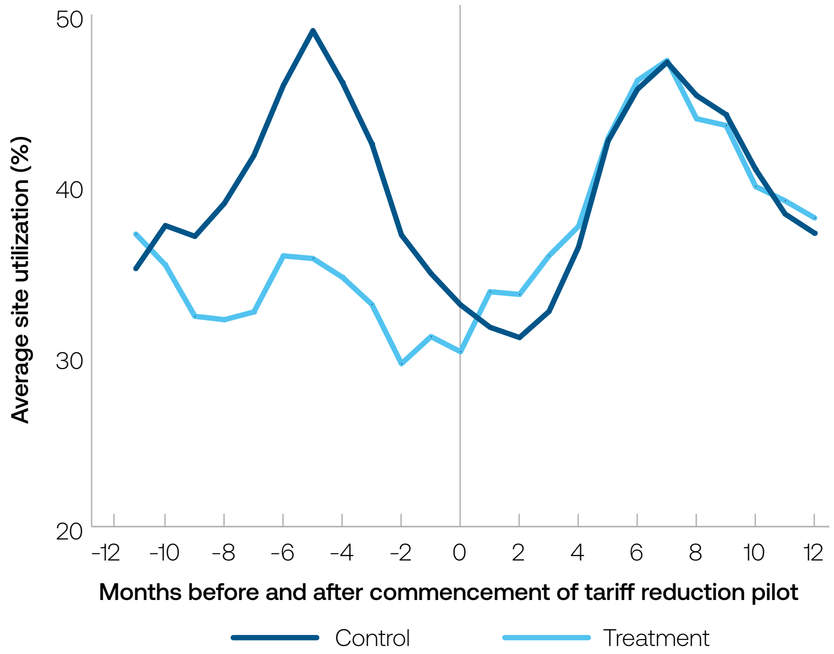
What it means

Fundamentally, higher reliability simply provides more time for consumption across sites. Furthermore, **electricity reliability gives consumers confidence in investing in appliances and income generating machinery** that allow them to consume more.

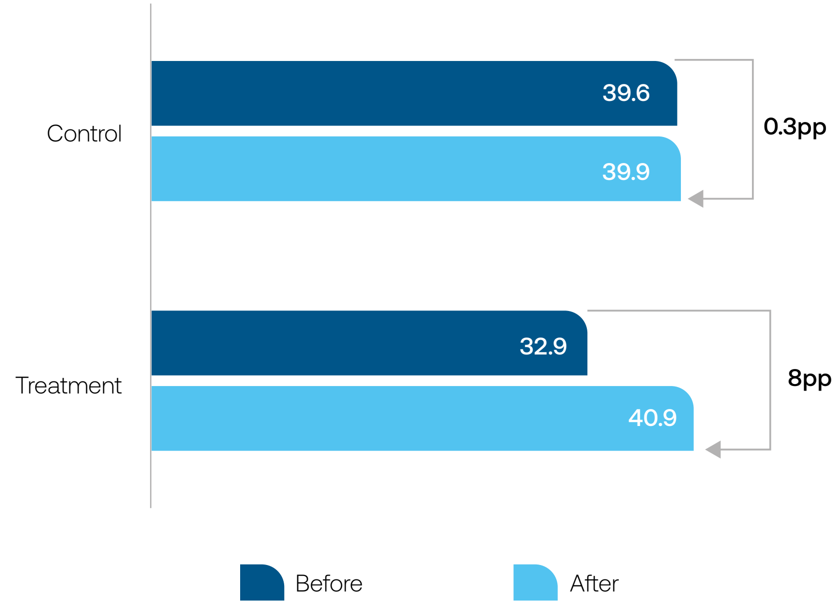
Customers on control sites with no tariff reduction but high reliability consumed more due to this higher trust. Sites with high reliability and tariff reduction saw **even further increased consumption because of higher affordability.**

Increased consumption has helped to increase site utilization across treatment sites by 24%

Average site utilization across treatment and control sites (%)



Average site utilization over 12 months before and after treatment (%)



Utilization is calculated as the ratio of actual meter consumption to the maximum potential energy generation. The maximum potential energy generation is derived from the total energy that could be generated by the PV solar panels based on solar irradiance data from the Solar Atlas, factoring in a 30% potential energy loss
Before = Months -11 to 0; After = Months 0 to 11

What we're seeing

Utilization is defined here as the percentage of the total installed generation capacity that is being utilized for consumption by the connected end-users over a given time period.

Site utilization was lower on treatment sites than control sites prior to pilot launch.

Post pilot launch, utilization has **increased by 24% (8 pp) on treatment sites** compared to **1% (0.3pp) growth on control site.**

What it means

Tariff reduction has a positive impact on utilization rate. This is mainly driven by the increased consumption.

Furthermore, during the course of the pilot, two treatment sites underwent expansion in the months of August and November respectively– reducing the potential utilization increase that could have been observed.

In contrast, control sites do not experience an increase in their utilization since consumption does not significantly increase over the period.

Investing in mini-grid reliability has proven to increase utilization rates. This investment could entail expanding on-site capacity to allow for higher consumption, regular maintenance and replacement of batteries, and upkeep of MV lines. Enhanced customer service, including monthly site visits and quick turnaround for issues raised, also plays a crucial role in improving utilization.

02

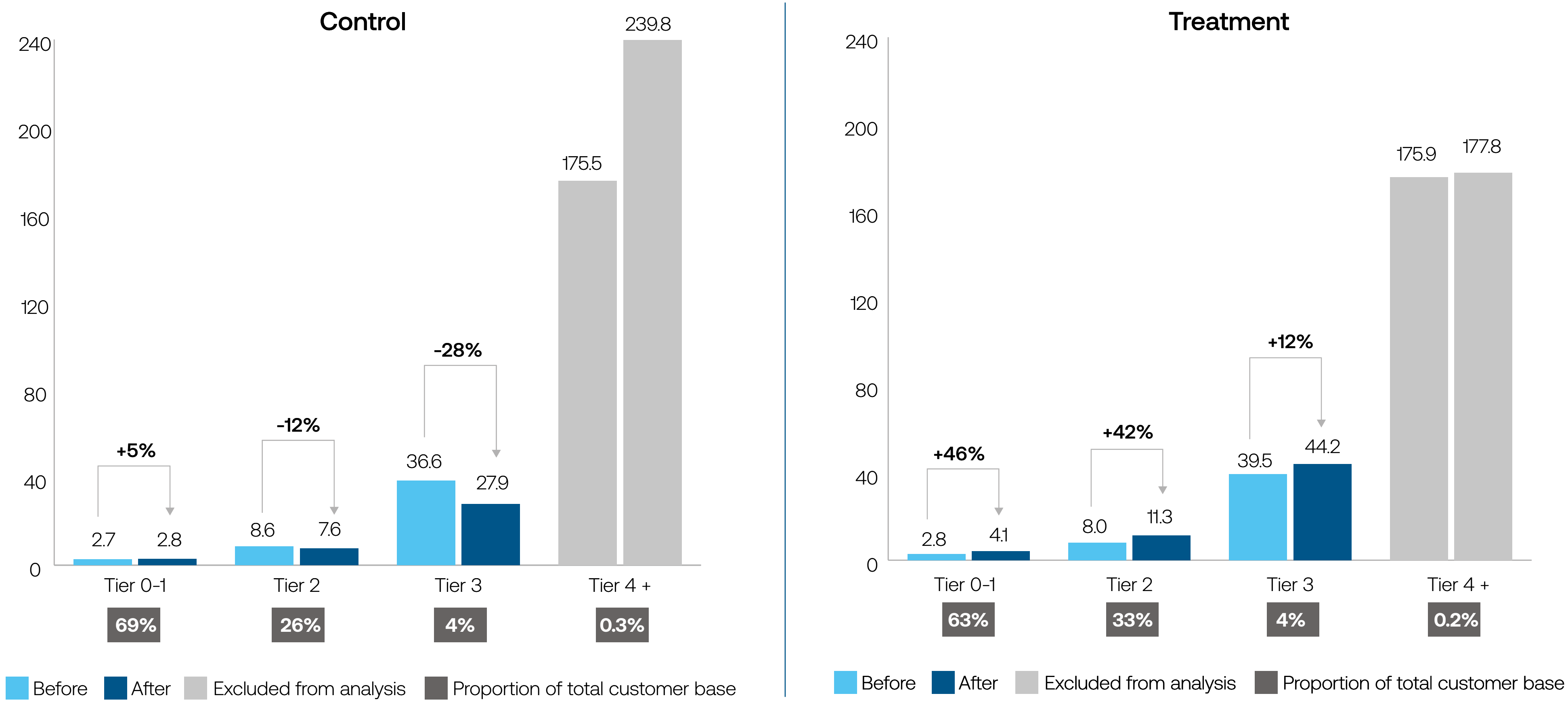
The lowest consuming customers benefit the most from tariff reduction.


Image: © Sameer Halai, Co-Founder of SunFunder/Flickr


PowerBox

Reducing tariffs has the highest impact on the lowest-consuming, and likely lowest-income customers as their ability to consume within their energy budget remains constant

Median consumption across different customer segments after tariff reduction (kWh/month)



Consumption categories are based on the ESMAP Multi-tier framework. Tier 0: Below 0.012 kWh/day, Tier 1: Between 0.012 and 0.2 kWh/day, Tier 2: Between 0.2 and 1 kWh/day, Tier 3: Between 1 and 3.4 kWh/day. Tier 4: Between 3.4 and 8.2 kWh/day. Before = Months -11 to 0; After = Months 0 to 11

What we're seeing

Increase in median ACPU is observed across all treatment categories, while in control sites increases are observed in Tier 0-1 and 4+.

Tier 0-1 constitutes 63% of customers across treatment sites and their ACPU increased by 46% compared to just 5% on control sites.

Tier 4+ customers are commercial users and clinics with average daily consumption of 3kWh and 6.6kWh respectively. Only 8 customers out of 3300+ qualified as Tier 4+ in the pilot - these 8 customers were excluded from the analysis to prevent individual outlier values from disproportionately influencing the results.

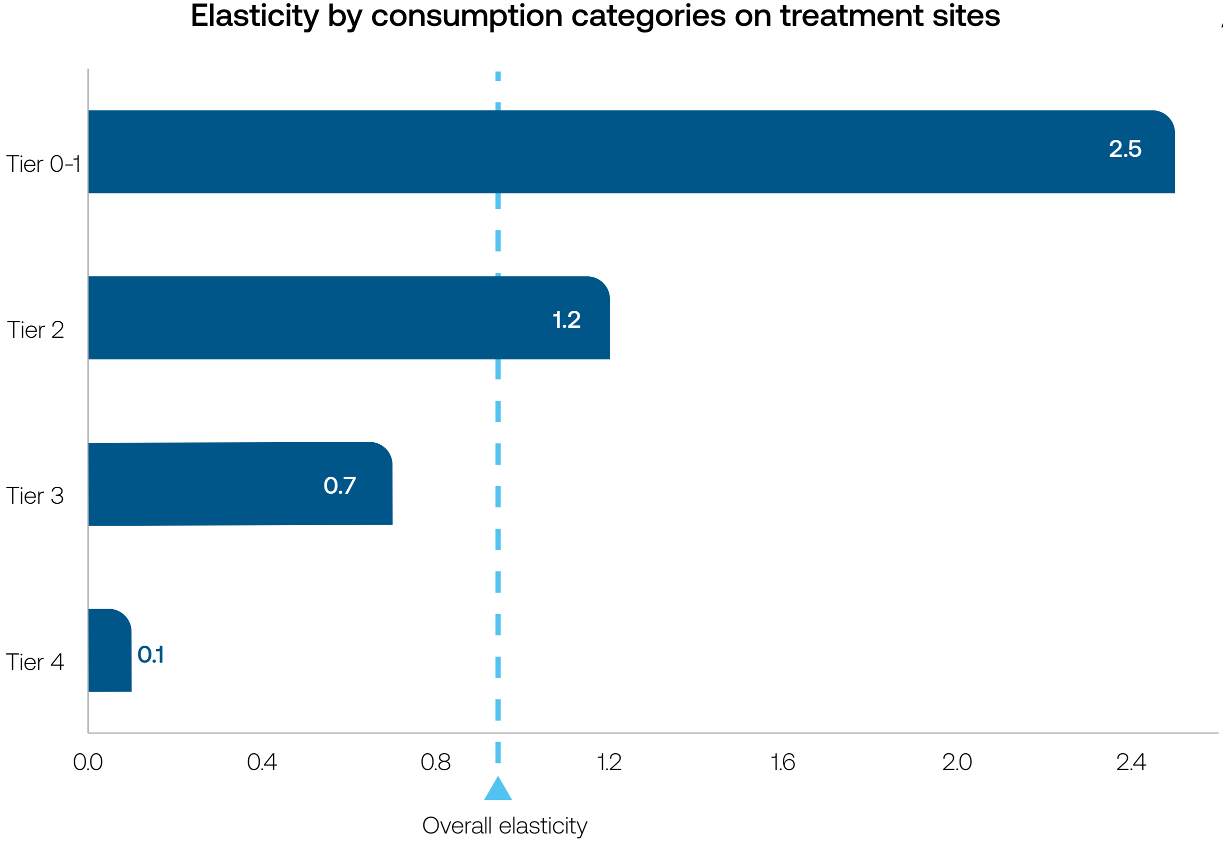
What it means

Tariff reduction benefits low-consuming customers, particularly those in Tier 3 and below, who are presumed to be the lowest-income earners.

This reduction in tariff enables them to slightly increase their consumption within their fixed energy budget, enhancing the value they derive from their electricity connection. Though these customers are still relatively low consumers (~4kWh per month) their **cumulative impact on overall consumption is significant.**

On the other hand, Tier 0-1 customers on control sites have a more modest increase (0.1kWh) as their energy budget remains constant.

The price elasticity of demand varies significantly based on the consumer's income level and the consumption category, with the lowest tier consumers exhibiting the highest price sensitivity



	Average ACPU per Tier (kWh)	Total subsidy per Tier ('000, US$)[1]
Tier 0-1	4	64
Tier 2	11	31
Tier 3	44	9
Tier 4	178	2

1. Consumption categories are based on the ESMAP's Multi-tier framework. Tier 0: Below 0.012 kWh/day, Tier 1: Between 0.012 and 0.2 kWh/day, Tier 2: Between 0.2 and 1 kWh/day, Tier 3: Between 1 and 3.4 kWh/day. 0 represents the year before the pilot and 1 the year after the pilot. Tier 4: Between 3.4 and 8.2 kWh/day. Total subsidy is calculated using the formula set out in page 4 for the period beginning Nov. 22 to Nov. 23.

Price Elasticity

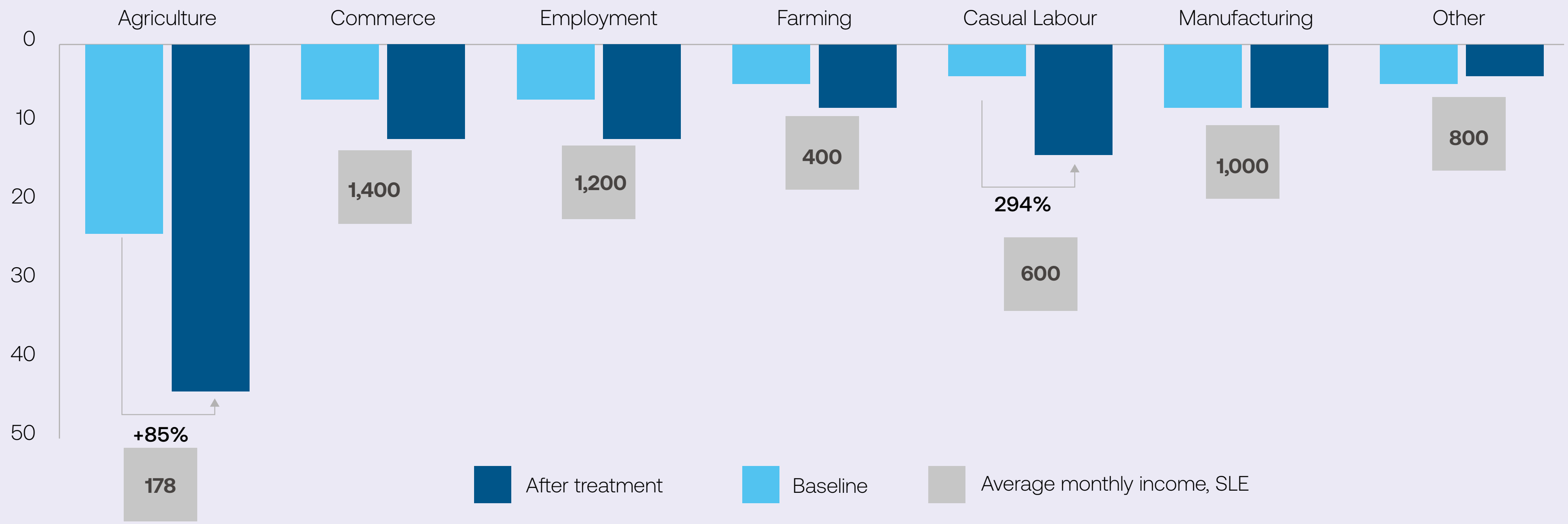
- Price elasticity of demand refers to the ratio of the consumption increase factor to the tariff reduction factor

$$\text{Price Elasticity} = \frac{\text{(change in average consumption)}}{\text{(change in tariff)}}$$

- It measures how sensitive consumers are to changes in the price of electricity
- Elasticity is important in helping set an optimal price that would maximizes consumption, revenue and/ or profit
- An elasticity of 1 means consumption increase factor is same as tariff reduction factor
- The pilot had an overall price elasticity of 0.87, while Tier 0-1 customers had an elasticity of 2.5 and Tier 4 customers had an elasticity of just 0.1:
  - The lowest consuming customers are most sensitive to changes in electricity tariff, and increase their consumption by several factors when tariff is reduced
  - On the other hand, high consuming customers tend to consume the same/slightly increase consumption for the same reduction in tariff
- The total subsidy is greater in lower tiers primarily driven by their larger customer base. Although Tier 4+ customers have the highest ACPU, they are fewer in number (4 customers per site) compared to Tier 1 and Tier 2 customers (993 and 533 respectively)

Further segmentation of the Tier data confirms this finding – casual laborers with no fixed monthly income increased their consumption the most

Median consumption across different income segments on treatment sites based on survey data (kWh/month)



The survey was administered to 311 respondents representing 10% of the customers in the study
The income segments are grouped as the following; 'Commerce' consists of small-scale commerce, services, remittance; 'Labor' consists of casual labor; 'Farming' consists of subsistence and commercial farming; 'Agriculture' consists of use of PUE in agriculture; 'Employment' consists of formally employed and pension; Manufacturing; and Other consists of blank responses as well as non-listed categories

SURVEY DETAILS

- Surveys were administered to a 10% sample of pilot participants across sites
- Analysis of the survey data examining the relationship between income sources and consumption patterns revealed varying responses to tariff reduction.
  - The Casual Labour income segment, representing the second lowest income earners after farmers, with no fixed income and ad-hoc work opportunities benefited the most from the tariff reduction increasing their consumption by 294%
  - Those in the agriculture segment increased their consumption by 85%, which could be attributed to increased use of productive use appliances and income generating machinery
- While further investigation is needed to substantiate these survey findings and uncover the drivers of the consumption behaviour across these income segments, the data supports the hypothesis that the lowest consuming customers benefit the most from tariff reduction
- If tariffs were to be normalized, we expect consumers to adjust their consumption patterns to align with their fixed energy budgets:
- However, the impact may vary across different sectors and market segments – businesses are likely to be the least impacted as they need to fulfill their business obligations/ meet customer demand regardless of tariff

CONSUMER FEEDBACK

Customers are demanding more appliances, have increased business productivity and have expanded their social welfare activities in response to tariff reduction on treatment sites

Surge in Appliance Demand

Field data indicates a notable rise in demand for appliances, fueled by available financing solutions through partnerships with Easy Solar and the CARE program's asset financing offerings.

"Tariff reduction has greatly benefitted my business. I run a freezer, fan and TV more consistently now, thus improving my operations."

Business Growth

Reduced tariffs are attracting new commercial entities to consume on the grid while motivating existing businesses to consume more.

"Tariff reduction has been a blessing. As a businesswoman, my profits have gone up as a result of my electricity expenses going down. Moreover, the reduction has also provided longer study hours for my children"

Expanded Social Welfare

The reduction in tariffs has enabled the reallocation of community resources, thereby enhancing societal welfare.

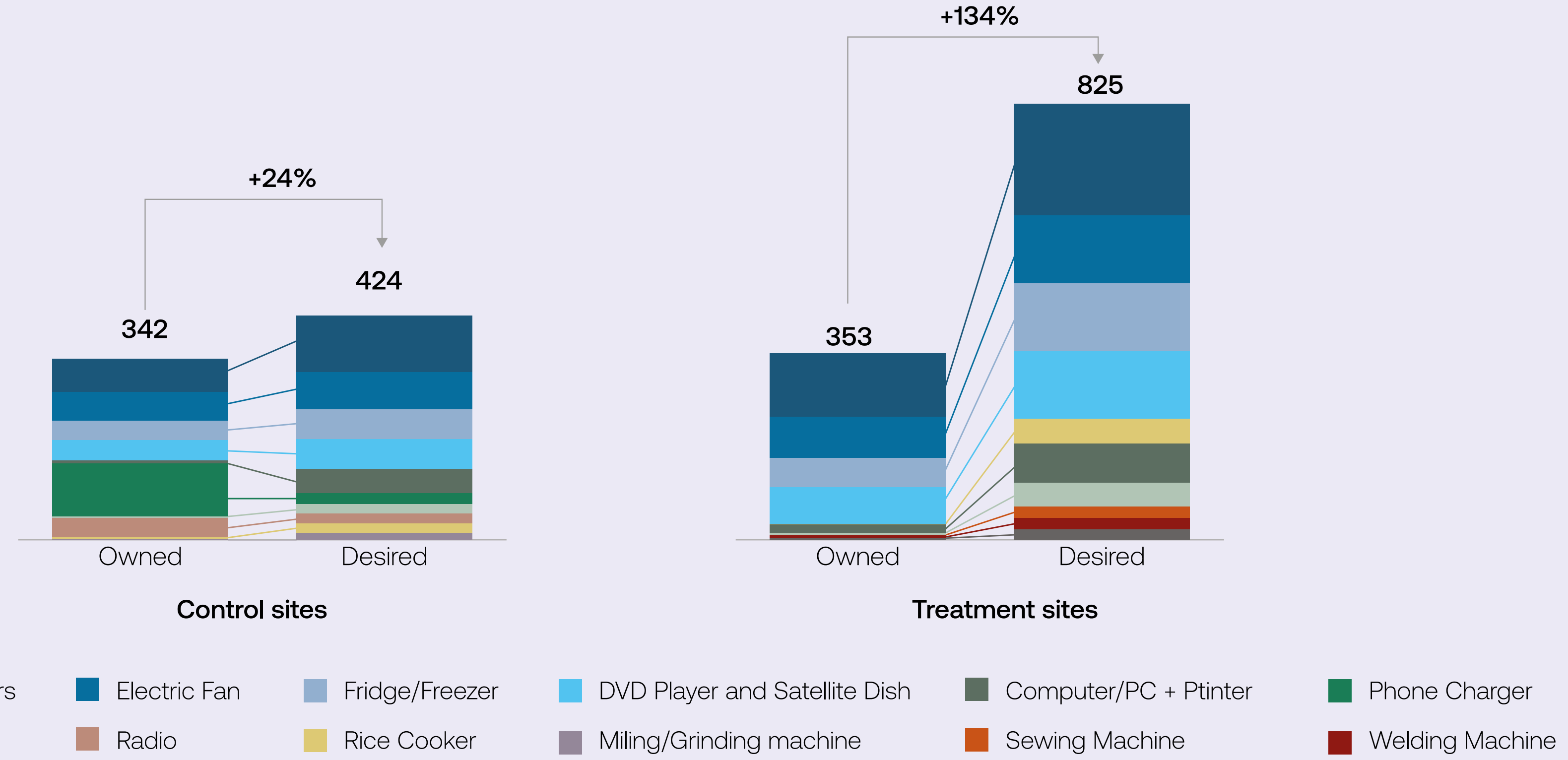
"When tariffs were reduced, a longtime philanthropist who had been subsidizing tariffs in Rokonta repurposed their funds to establish a community recreational center, aimed at enhancing the overall quality of life for local residents."

Source: Insights from pilot administrators (Manocap advisory) reports


Image: © Olooji Community

Survey respondents in both treatment and control sites expressed interest in acquiring more appliances, however, the demand in treatment sites was notably higher than in control sites

Appliances Owned vs Desired across both Treatment and Control sites (#)



The following appliances were considered in this analysis: Blender, Blow / Hair dryer, Computer / PC, DVD player, Decoder, Egg incubator, Electric Power tools, Electric fan, Fridge/ freezer, Generator, Hair clipper/shaver, Iron, Irrigation pump, Milling/Grinding machine, Phone charger, Photocopier, Printer, Radio, Rice cooker, Satellite Dish, Sewing machine, Speakers/ woofers, TV, Water dispenser, Welding machine. However, only the top 10 most desired appliances in both control and treatment sites have been included in the above analysis.

SURVEY DETAILS

- Tariff reduction has led to a 134% increase in consumers on treatment sites desiring multiple, larger appliances compared to 24% increase in control sites
- This implies low tariffs, coupled with increased reliability, gives consumers more confidence that they can purchase appliances and consume electricity within their energy budgets
- Across both sets of sites, household appliances such as TVs, speakers and fans were the most desired appliances; with freezers being the most desired commercial appliances

SURVEY ANALYSIS

Survey respondents across treatment and control sites reported satisfaction with electricity access, citing increased study time, higher income, and better health outcomes

Key Drivers of Customer Satisfaction with Electricity Services (%)

The survey was administered to 311 respondents representing 10% of the customers in the study

SURVEY DETAILS

- All survey respondents acknowledged that having access to electricity has significantly improved their lives.
- Even without a reduction in tariffs, the availability of electricity in these communities has positively contributed to higher income generation, increased study time and school attendance for children, and improved access to healthcare services.
- Survey analysis show that only 12% of the total respondents from developer 2 and 3 were unhappy with their electricity service citing unreliability and high electricity costs, while all of developer 1 respondents were happy with their electricity service

03

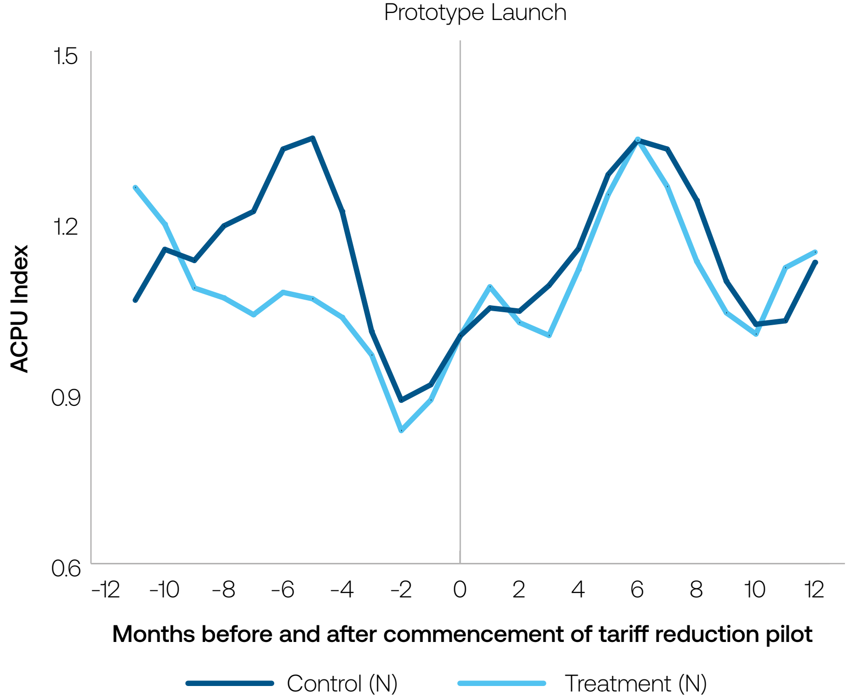
Developers can lower tariffs and increase revenues in local currency, but this may not hold true in hard currency or when taking into account inflationary impacts.

Image: © UNOPS/Flickr

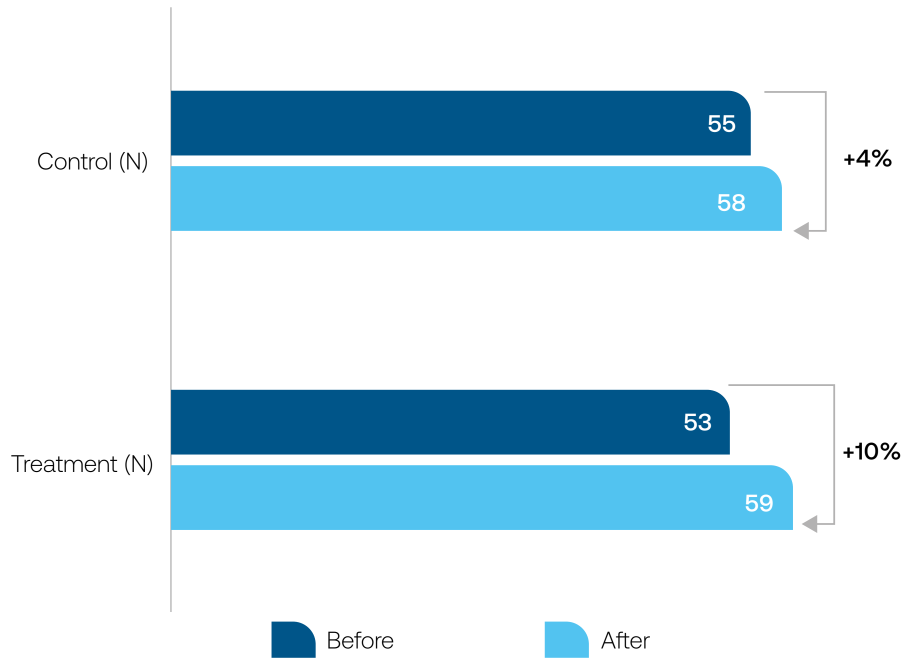

PowerGen

Despite a 41% tariff reduction, average revenue per user (ARPU) in nominal terms has increased on treatment sites

ARPU across treatment and control sites – Nominal (N), (SLE)



Average ARPU over 12 months before and after treatment – Nominal (N), (SLE)



The averages shown on the ARPU index are 3-month moving averages. The averages are computed at the site level rather than the consumer individual meter level considering contextual differences across sites

ARPU index is calculated by dividing the average at any month by the average at month 0

Note: Before = Months -11 to 0; After = Months 0 to 11

The old Leone currency was redenominated by a factor of 3 in July of 2022 and this was implemented on sites over different time periods, and this has been taken into account in our analysis

What we're seeing

Although tariffs were reduced by 41%, the average revenue per user (ARPU) at **treatment sites increased by 10% in SLE.**

On control sites a 4% increase was observed.

What it means

Consumption increase as a result of tariff subsidy is **significant enough to offset and even surpass the effects of tariff reduction in revenue generation for treatment sites.**

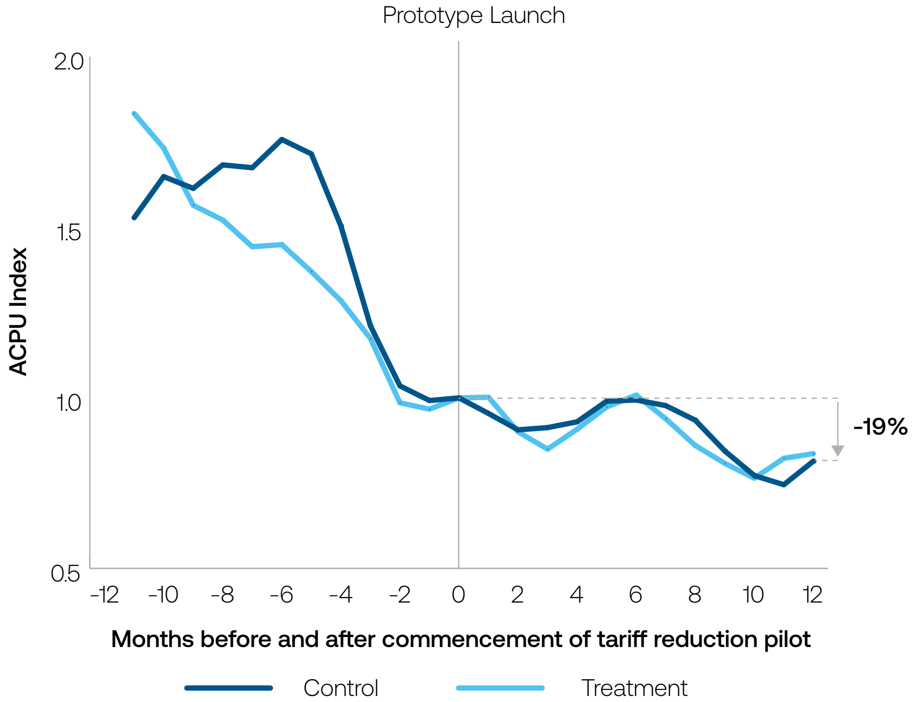
The increase in control sites can be attributed to the organic growth.

At month 10 into the pilot, the growth in ACPU on treatment sites has turned an ARPU deficit to a net positive with treatment sites arriving at the same ARPU as control sites or even higher.

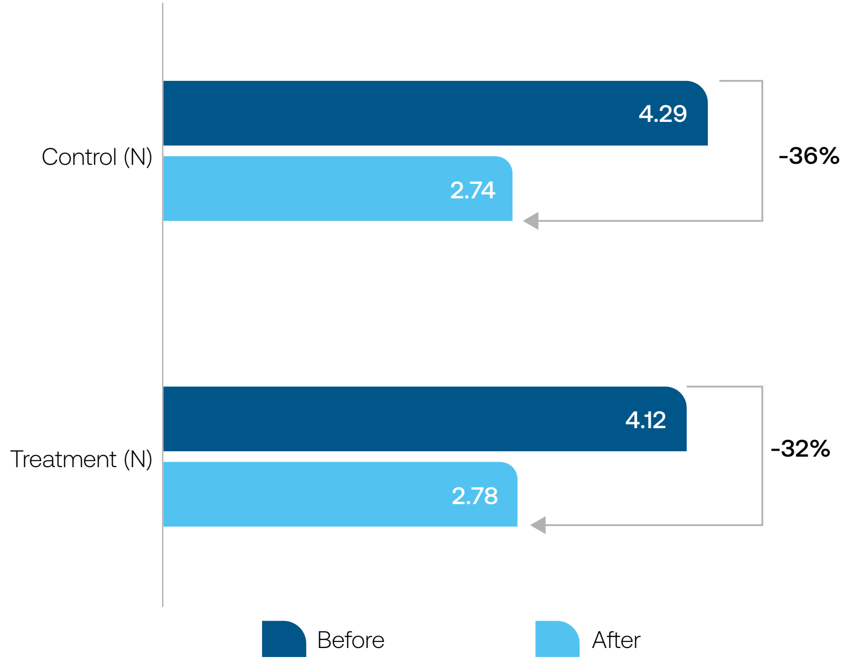
This further shows that **developers could reduce tariffs with little to no subsidy in stable economic conditions – however** capacity increases would require additional funding.

While ARPU has increased in local currency, in dollar terms nominal ARPU has decreased by more than 30% for all sites

Average revenue per user (ARPU) across treatment and control sites – Nominal (N), (US$)



Average ARPU over 12 months before and after treatment – Nominal (N), (US$)



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The old Leone currency was redenominated by a factor of 3 in July of 2022 and this was implemented on sites over different time periods, and this has been taken into account in our analysis

What we're seeing

Revenues in dollar terms **decreased by more than 30% in both treatment and control sites.**

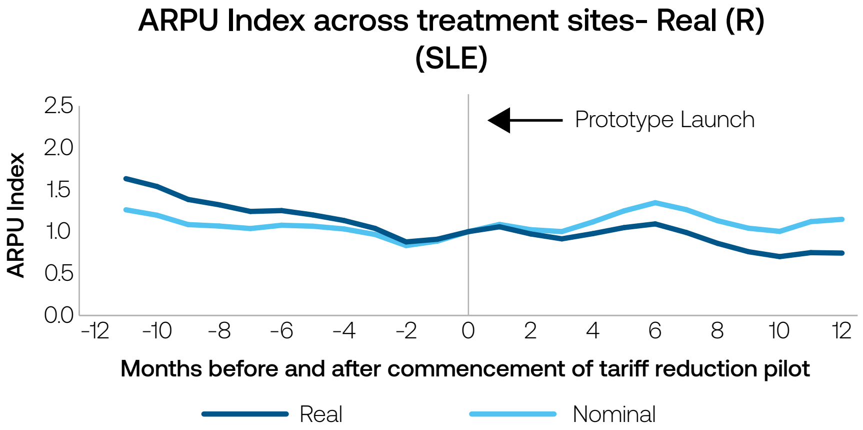
What it means

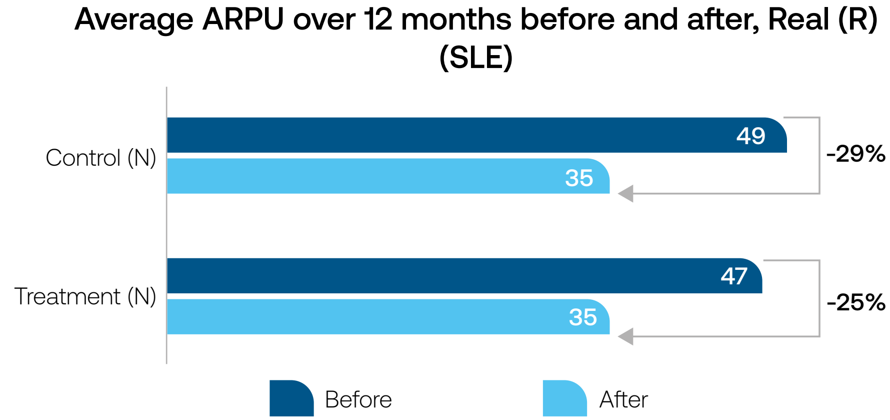
The substantial decline in ARPU denominated in US$ can be attributed to the devaluation of the Sierra Leonean Leone (SLE).

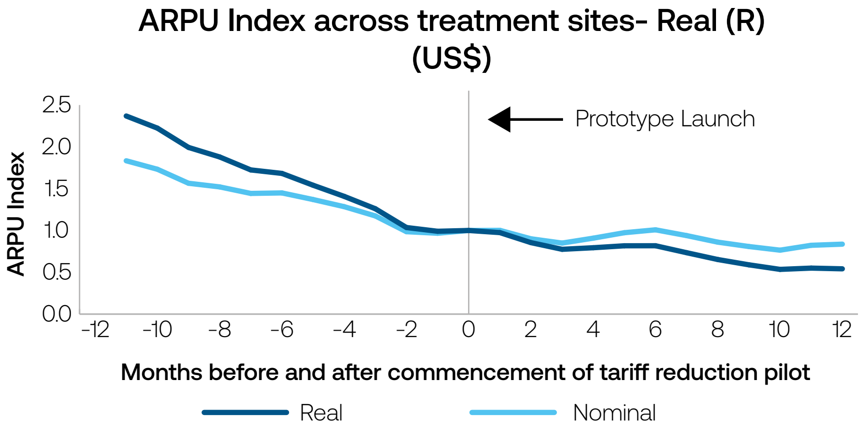
Since the start of the pilot project, the SLE has experienced a significant depreciation. Despite the effective tariff remaining unchanged at SLE 7.527 (initially equivalent to US$ 0.58), its US Dollar equivalent has decreased considerably to US$ 0.34.

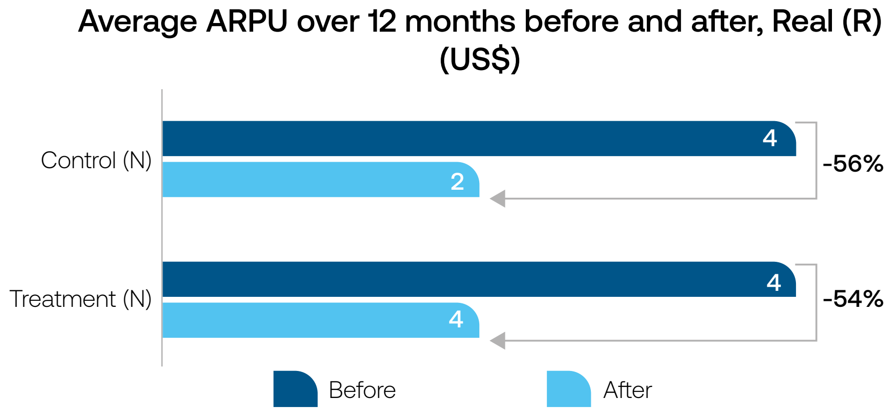
While the unchanged tariff in local currency terms has made energy more affordable for consumers, as will be discussed in subsequent slides, this has posed operational sustainability challenges for developers, who incur a portion of their costs in hard currency. Access to local currency financing could be crucial for offsetting the impacts of currency devaluations on project economics. Alternatively, a hedging mechanism to counter devaluation impacts could address this challenge.

In real value, ARPU in both local currency and US$ has decreased by more than 30%









The averages shown on the ARPU index are 3-month moving averages. The averages are computed at the site level rather than the consumer individual meter level considering contextual differences across sites
ARPU index is calculated by dividing the average at any month by the average at month 0
Note: Before = Months -11 to 0; After = Months 0 to 11
The old Leone currency was redenominated by a factor of 3 in July of 2022 and this was implemented on sites over different time periods, and this has been taken into account in our analysis
November 2021 Consumer Price Index (CPI) = 100

What we're seeing

Although nominal ARPU in local currency (SLE) increased, **the real ARPU substantially decreased.**

The real ARPU in US$ also experienced a decrease, however, the delta decrease in US$ (-54%) was wider compared to the SLE delta (-25%) due to devaluation of the currency.

What it means

The actual purchasing power of revenues during the pilot has diminished significantly.

The decline in real ARPU suggests that developers are facing increased financial pressure. Even though they may be earning more in nominal local currency terms, the real value of their income in local currency has decreased, making it harder to cover operational costs and investments. The impact is even worse for developers incurring costs in hard currencies while receiving revenues in local currencies.

The real ARPU decline underscores the importance of developers and sector at large implementing strategies to hedge against currency risks. To maintain real value of mini grid revenues, developers can implement currency hedging strategies or adopt inflation-indexed tariffs (requires approval by the EWRC). Additionally, focusing on operational efficiency and securing local currency financing could help mitigate the impact of currency risks on revenues.

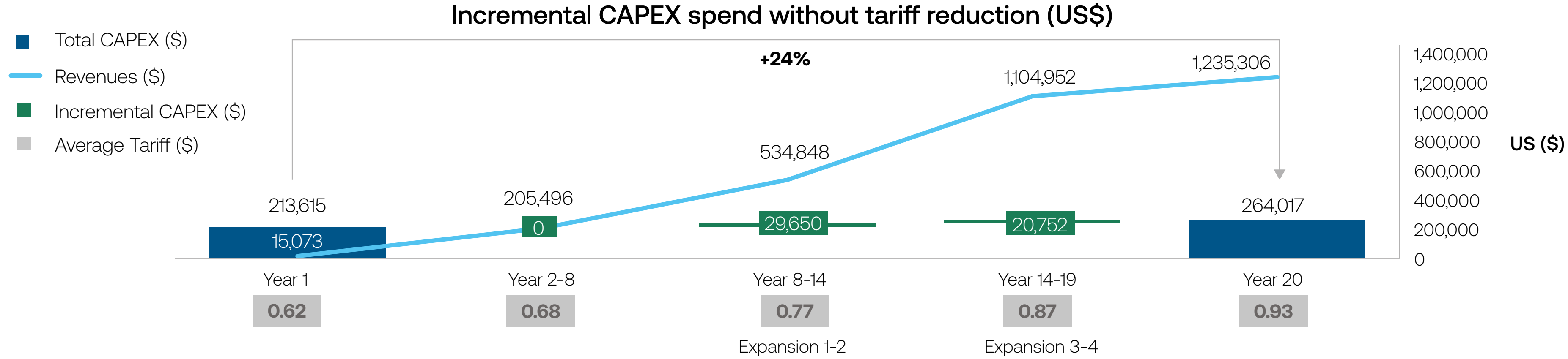
Assumptions were derived from all three developers' business models to provide a basis for modelling a "typical" mini-grid in Sierra Leone

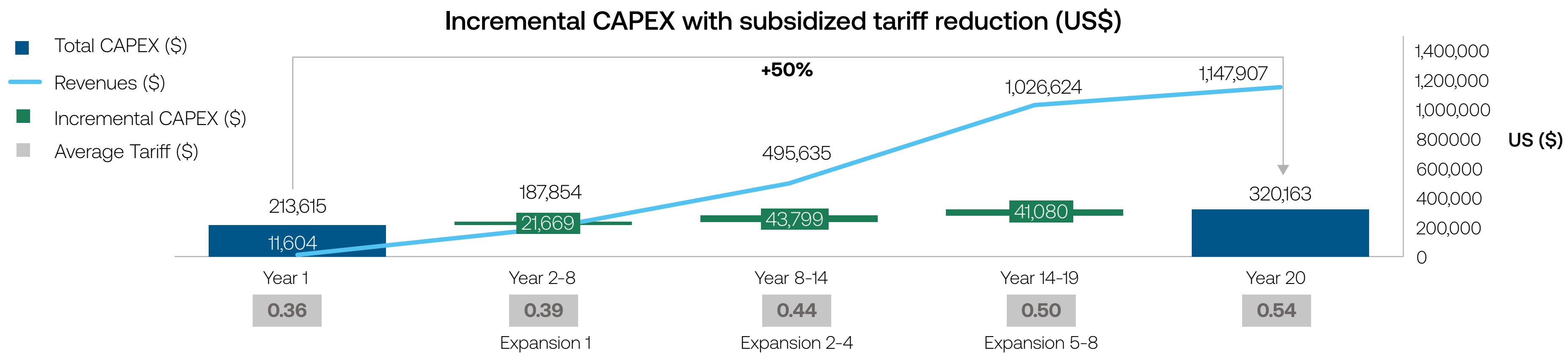
Category	Assumptions
Consumption	• BAU : Initial average ACPU of 7.1 kWh/month, growing at an average of 14.6% p.a. in the first 4 years and 5% p.a. at scale. • Households - Initial average ACPU of 7.1 kWh/month growing at an average of 23.3% p.a. in the first 4 years and 5% p.a. at scale. • Productive use - Initial average ACPU of 33.9 kWh/month, 3% p.a. • Households' connection growth at 3% p.a., productive use connection growth at 1% p.a.
Tariff	• CapEx in BAU scenario assumes tariff of SLE 7.527 (US$ 0.58). • CapEx without subsidy assumes a tariff of SLE 4.439 (US$ 0.34).
RBF (Result Based Financing - Subsidy)	• Irrespective of tariff reduction, the model assumes RBF Grants for CapEx at US$ 651.20 per connection at site establishment. **NOTE**: All developers have CapEx grants in their base case scenario.
Inflation & Depreciation	• The model accounts for inflation at average of 10.4% p.a. • The model also accounts for currency depreciation at CAGR of 6.35%, which impacts the real value of revenues over time.
Cost of Capital	• A 15% Weighted average cost of capital (WACC). While the average industry standard is 10%, we have adopted a more conservative 15% WACC to reflect the macro economic conditions in Sierra Leone.
Currency	• All financial projections are calculated in US$ though revenues being received in Sierra Leonean Leone (SLE)

Source: CrossBoundary Innovation Lab Tariff Harmonization Model, Developer models, RBF Grants Benchmark across Sierra Leone Developers


Image: © Obadore Community

Additional revenues from higher consumption partially offset CapEx requirements for meeting demand, but developers still require some subsidy support for a lucrative business case





Source: CrossBoundary Innovation Lab Tariff Harmonization Model, RBF Grants Benchmark across Sierra Leone Developers

What we're seeing

Without tariff reduction, consumption grows organically, reducing the pressure for frequent capacity expansions (expansion only occurs 4 times over the duration of the project). CapEx increases by 24% under this scenario,.

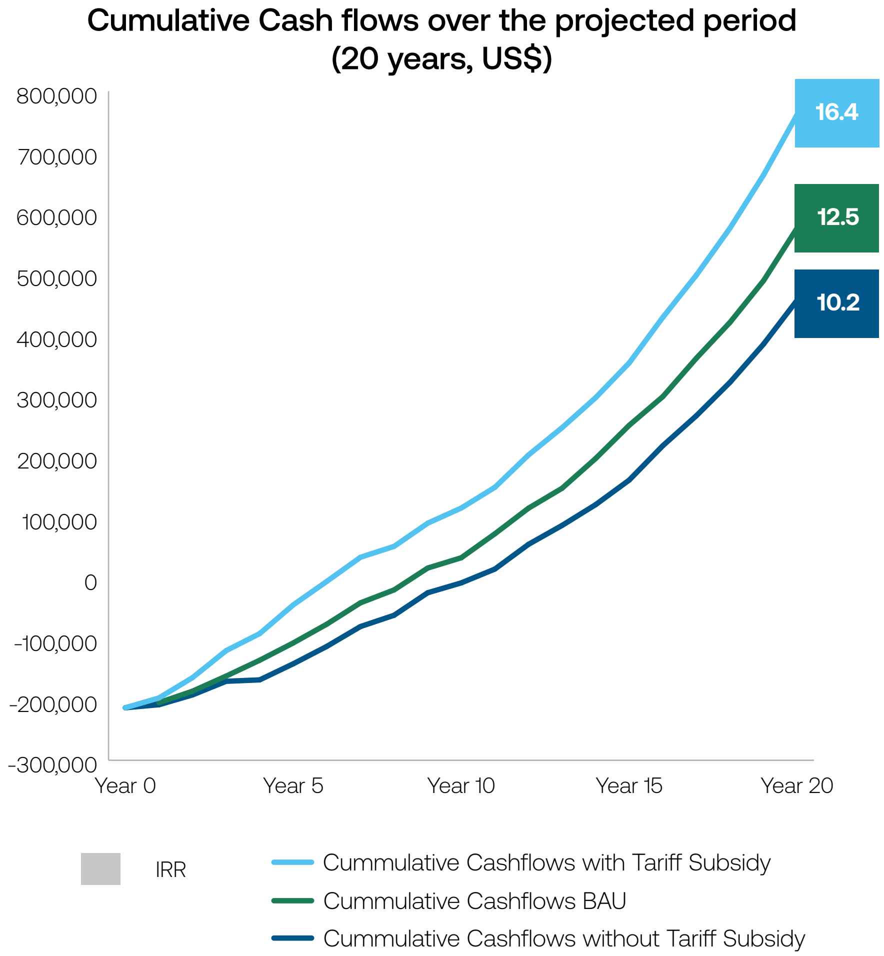
With tariff reduction, developers will need to expand their sites more often (7 times over the project's duration) to match the increased consumption. This leads to a more substantial 50% increase in CapEx over the same period.

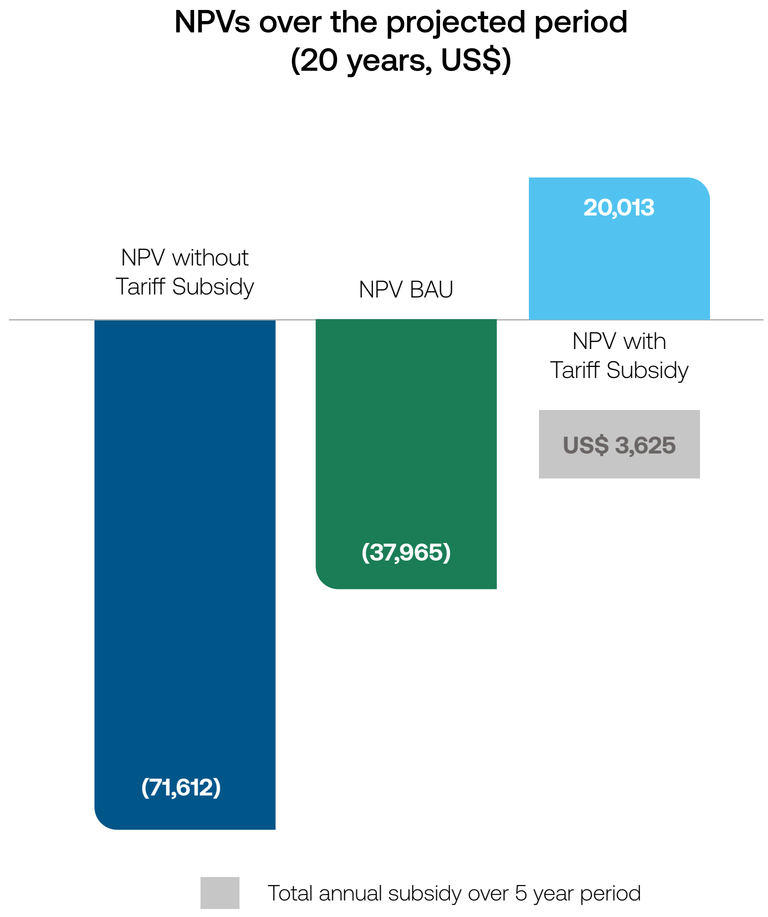
What it means

Developers could reduce tariffs, and with increased earnings from this reduction, they would be able to cover CapEx expansions without tariff subsidy. However, the developers would likely still require some form of subsidy to meet return on investment requirements (further detailed on next page).

NOTE: All of the developers' financial models include a CapEx subsidy as base case. The main subsidy programs include UNOPS for WP-1 and WP-2 and Sustainable Energy for All (SEforALL) - Universal Energy Facility (UEF).

While an IRR of 10.2% is achievable across sites without tariff subsidies, this still falls short of the 15% threshold sought by investors for a compelling business case for countries like Sierra Leone





Source: CrossBoundary Innovation Lab Tariff Harmonization Model, RBF Grants Benchmark across Sierra Leone Developers

What we're seeing

The cash flow chart shows that with the tariff subsidy, cumulative cash flows turn positive earlier and increase more rapidly, resulting in a 16.4% IRR and an NPV of 20,013. In contrast, the no-subsidy scenario produces a 10.2% IRR and an NPV of (71,612).

What it means

Even without tariff subsidies, minigrid sites could have positive returns at 10.2%. However, this falls short of the BAU scenario IRR of 12.5%, as such, it is insufficient to motivate developers to reduce tariffs without subsidies.

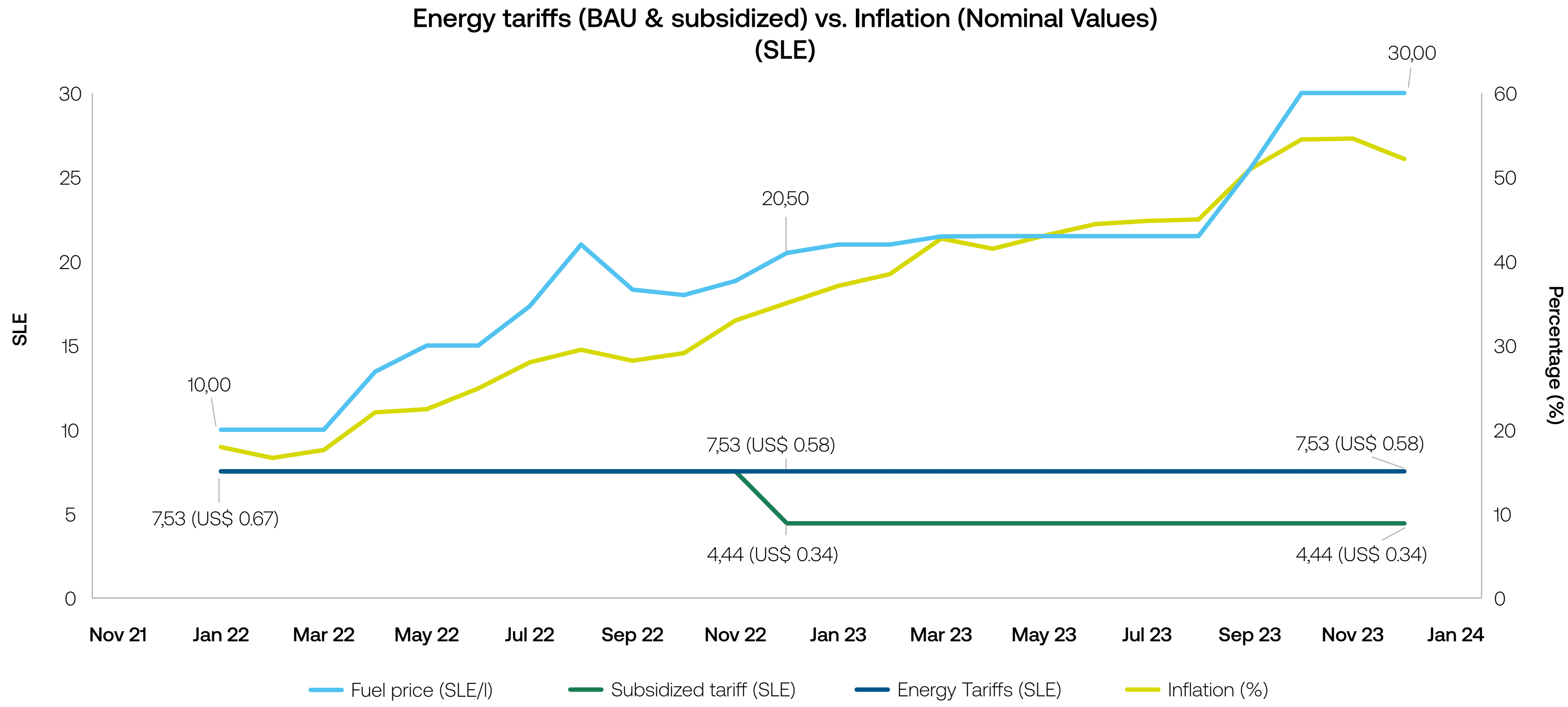
Furthermore, a 10.2% IRR is inadequate to attract investment into a "high-risk country" such as Sierra Leone, which has experienced significant upheavals and challenges in the past ten years. As such most investors aim for returns above 15% in this market.

Consequently, the implementation of tariff subsidies—whether through government programs or alternative funding mechanisms — is crucial as an incentive for developers to reduce tariffs for lowest consuming customers in Sierra Leone and other challenging geographies.

04

Macroeconomic challenges have significantly impacted developer operations.

Rising inflation, while the energy tariff remains stagnant, has impacted the viability of developers to meet their operational needs



Source: World Bank, EWRC

What we're seeing

Tariff rates have remained relatively stagnant since pilot launch while inflation has risen by +23 basis points (bp) and fuel prices increased by 46% over the same period.[1]

Impact on developers

High inflation has led to increased operational costs at developer sites. The increase in inflation has put upward pressure on fuel prices. Given that developers are operating at the same tariff (not adjusted to inflation), developers purchased less fuel which led to some of the sites' generators not operating as required.

Impact on consumers

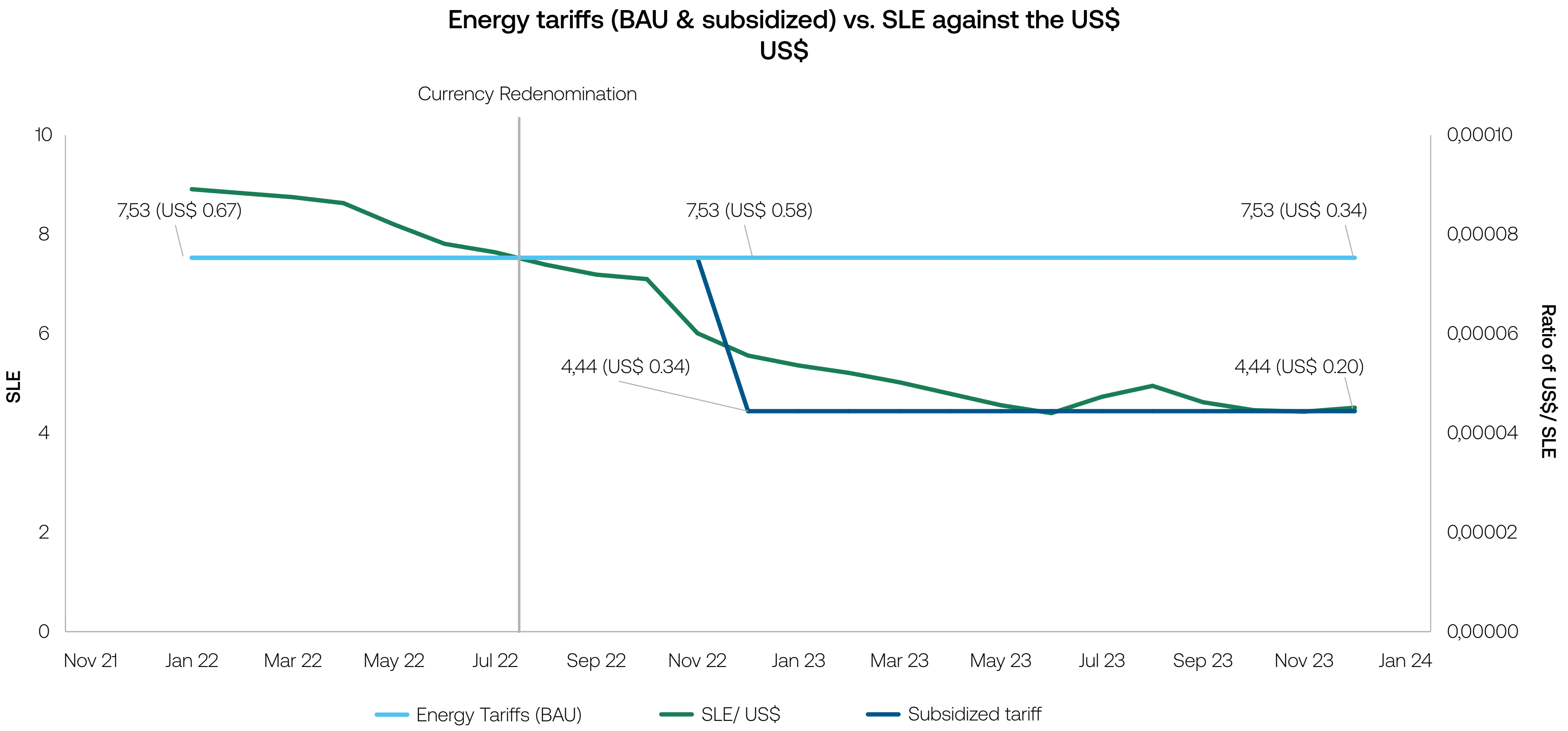
Challenges such as lack of fuel impact the electricity reliability subsequently impacting consumption. Lack of fuel means that the generators are not running when they. need to impacting the ability to consume on the grid.

What it means

The tariff subsidy's effectiveness hinges on either (i) a stable economy or (ii) hedging mechanisms to safeguard developers against the macroeconomic volatility.

1. Fuel data represents petrol, diesel, and kerosene. The price of fuel increases the further one moves away from urban centers . This is attributed to the absence of adequate infrastructure for transporting fuel efficiently to rural and remote regions, thereby driving up the associated costs.

In addition to the rising inflation, a weakening SLE has further constrained developers in meeting their financial obligations



Note: The SLE experienced a devaluation in July of 2022 and has continued to weaken against the US dollar. Note that the new currency post devaluation is denoted as SLE whilst the old currency is denoted as SLL.

What we're seeing

The BAU tariff in SLE has remained unchanged since the start of the pilot program. However, in US$, the tariff has decreased significantly due to the gradual weakening of the SLE against the US$.

Impact on developers

Developers are still collecting the same revenue in SLE terms since the beginning of the pilot program while incurring some of their expenses in hard currency.

Impact on consumers

The declining value of the SLE makes the energy tariff relatively cheaper in local currency terms

What it means

With a weakening local currency, developers' ability to meet financial obligations is further impacted. As with inflation, mitigating measures such as hedging strategies or local currency financing are necessary to offset the exposure.

05

Tariff reduction works and could be implemented at scale, but a suite of interventions is required for sustainability.


Image: © OFID/Mona Alessa/Flickr

Tariff reduction works – and results in significant increases in consumption which offset revenues impacts and boosts utilization.

The lowest consuming customers benefit the most, increasing their consumption significantly and experiencing improved quality of life.

However, these benefits are insufficient for developers to achieve a sufficiently bankable business-case to attract investment in "high risk" markets such as Sierra Leone.

To implement tariff reduction at scale, developers, governments and development partners need to consider a suite of interventions to make mini-grids sustainable and affordable for consumers. These could include:

01 A streamlined, efficient subsidy regime that maximises tariff reduction potential

- Capex subsidies prior to construction
- Tariff reduction subsidies for lower consuming tiers during operation

02 De-risking mechanisms including hedging funds for offsetting macro-economic risks and local currency financing


Image: © Energicity

01 A streamlined, efficient subsidy regime will consider subsidy type, timing and funding sources

- **A streamlined subsidy regime would consider what type of subsidy should be applied and when**
- Multiple subsidy programs have been implemented to various levels of success in different countries and across different programs. The different types of subsidies along the project life cycle include CapEx subsidies prior to construction, tariff reduction subsidies for lower consuming tiers during operation, and could include CapEx subsidies for expansion in the future
- Understanding which type of subsidy should be applied and when, is **critical for maximizing impact and funding efficiency**
- **A sustainable funding source is required to maintain these subsidies**
- Governments and donors have limited capacity to fund comprehensive subsidy regimes at scale
- Sustainable and recurring sources of funding for these subsidies could include implementation of micro-levies or cross-subsidies, which could be anchored by Government or development partner funding

Key outcomes

Optimal subsidy type e.g., results-based financing, capital expenditure subsidies, or tariff buy-down

Appropriate timing and modalities for their application

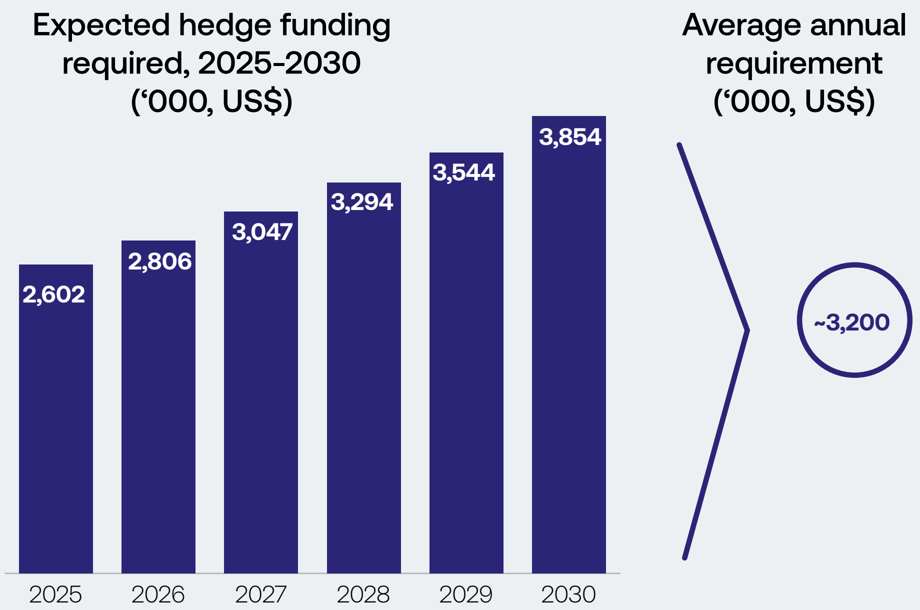
Potential sources of funding for these subsidies (micro-levies, development partners, cross-subsidy)

02 Putting in place a US$ 3.2M hedging fund could incentivize developers to lower tariffs

Hedging mechanisms to cover economic shocks such as currency devaluation are required to provide an additional incentives for minigrid developers to lower tariffs.

Our analysis suggests that an annual fund of ~$3.2M would be sufficient to hedge all minigrid sites in Sierra Leone. This hedging fund would be accessed to cover the difference in effective tariff in US$ terms following a devaluation event and would be claimed on a per kWh basis.

Such a fund would ensure the developer can meet foreign currency related obligations to investors and meet operational needs. The fund could only be used as needed and would roll-over as required, meaning once capitalized it might only require smaller annual top-ups. The need for such a fund could further be minimized by the provision of competitively priced local currency loans.



The hedge fund incorporates a US$ 0.41/kWh buffer to account for the 2023 currency devaluation. This buffer is applied to the projected annual consumption over five years. While the nominal devaluation is US$ 0.24/kWh ($0.58 baseline - US$ 0.34 2023 nominal post-devaluation), the US$ 0.41buffer reflects the real tariff adjustment considering inflation ($0.58 baseline - $0.16 2023 real post-devaluation). Consumption estimates are derived from the Lab’s 20-year tariff harmonization model projections, beginning January 2022.

Next steps

The next steps

The lab will leverage the data collected from the Sierra Leone Tariff Harmonization program pilot and other programs to collaborate with industry stakeholders, funders, and developers to provide a consolidated view on subsidies.

This will culminate in a report on how a streamlined, efficient subsidy regime could be applied and implemented on minigrids.

Expected outcome

With this further analysis:

- Funders will know the appropriate type of subsidy to fund and the optimal timing for funding these subsidies.
- Government and developers will know how best to utilize development funding, resulting in accelerated energy access.

Consequently, end-users, especially those with low incomes, will benefit from lower electricity tariffs.

Please contact **minigridslabs@crossboundary.com** for collaboration opportunities

The Innovation Lab's work is made possible by the following funders:

And by the following developers:

Disclaimer

The Lab is supported by the University of Massachusetts Amherst, Rochester Institute of Technology, and Duke University, who support experiment design and analysis of results. The Lab's work and the results presented here are strongly endorsed by the Africa Minigrid Developers Association (AMDA).

The Lab's Innovation Insight series provides ongoing, early insights on the prototypes so minigrid developers, governments, and funders can act on the results as they emerge. All results and analysis in these series is therefore shared as actionable business intelligence rather than scientific evidence.

While these series are not intended to meet the standards of an academic paper, the Lab will publish more complete reports at the end of each prototype, and has partnered with University of Massachusetts Amherst, Rochester Institute of Technology, and Duke University to publish academic papers on certain prototypes.

Appendix

A. Site Level Data

B. Additional ACPU Analysis

C. Additional Survey Analysis

D. Cost Reflective Tariff

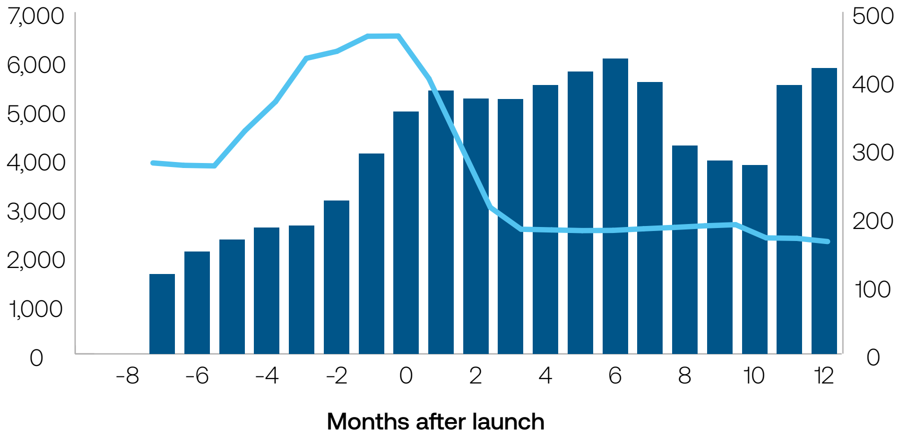
E. Subsidy Calculation

Image: © UNOPS/Flickr

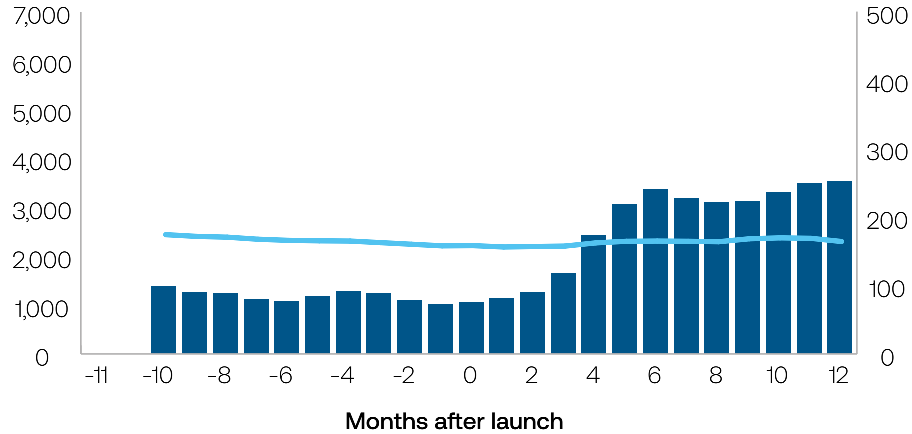
A1: Total consumption and meter count metrics across 8 treatment sites

Consumption Meter count

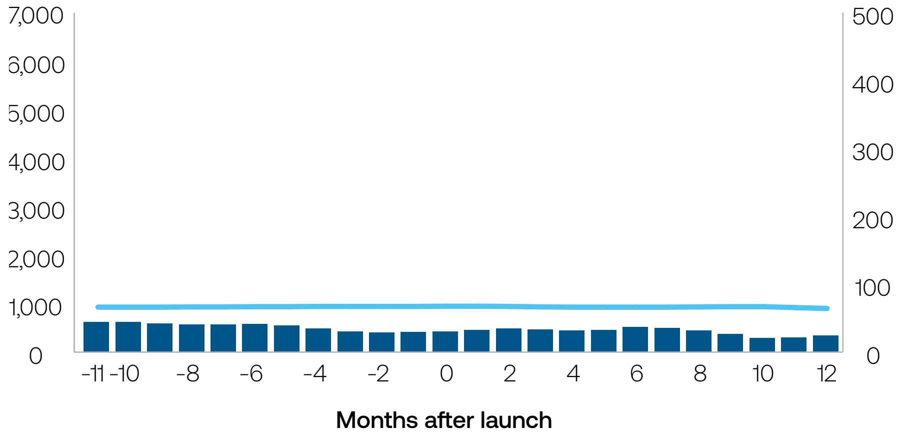
Rokupr



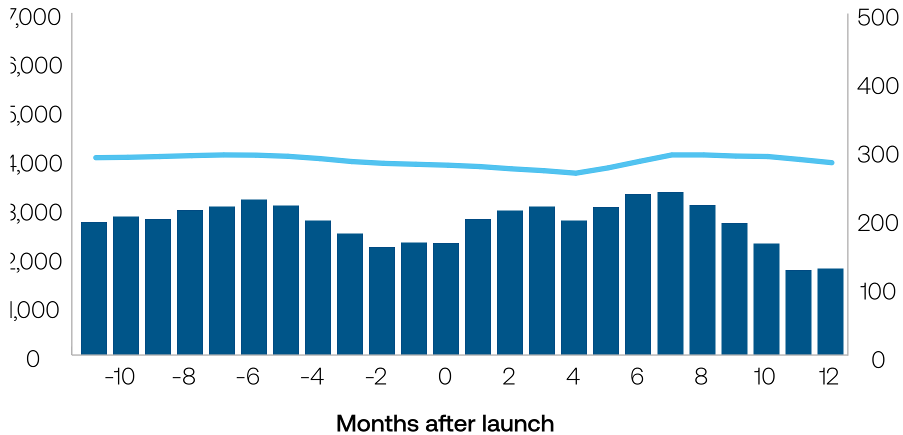
Conakry Dee



Gbap



Sulima

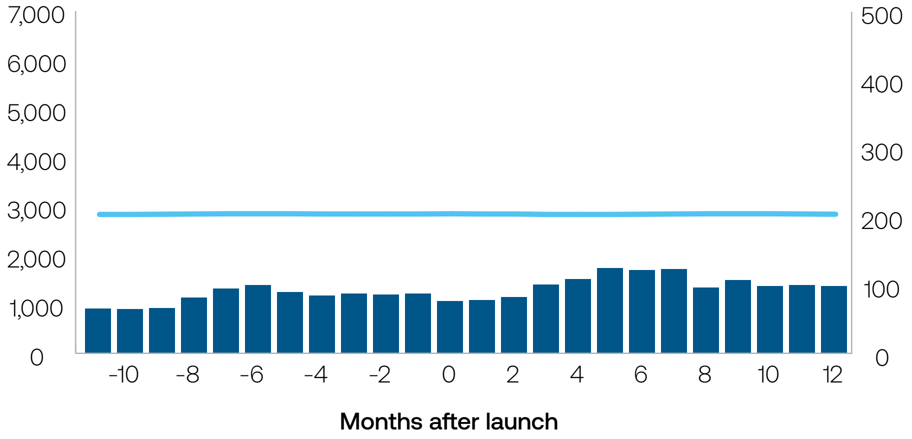


The pilot program coincided with appliance leasing initiatives like Easy Solar and the Global Energy Alliance for People and Planet's (GEAPP) Solar Harnessed Entrepreneurs (SHE) Project, which supplied productive use of energy (PUE) appliances to residential and commercial customers. Among our program sites, only Rokupr was influenced by the SHE project. However, its impact was minimal, with SHE appliances contributing just 7.4% to Rokupr's revenue and an insignificant amount to the total revenue across all eight treatment sites.

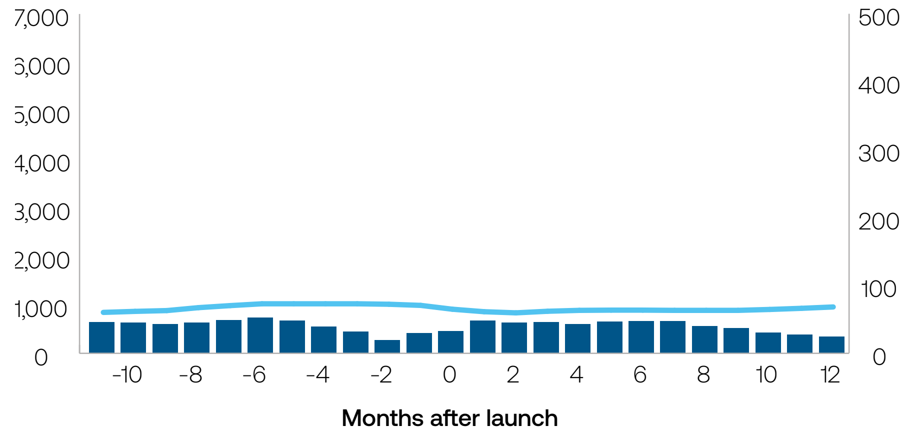
A1: Total consumption and meter count metrics across 8 treatment sites

Consumption   Meter

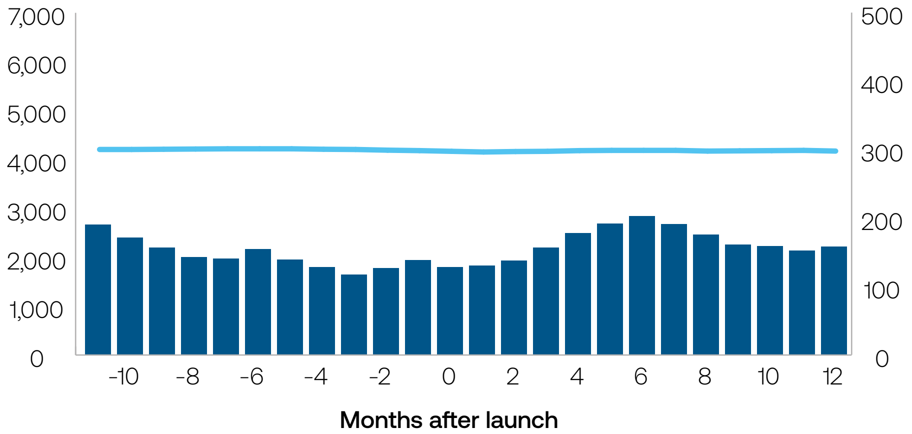
Kayima



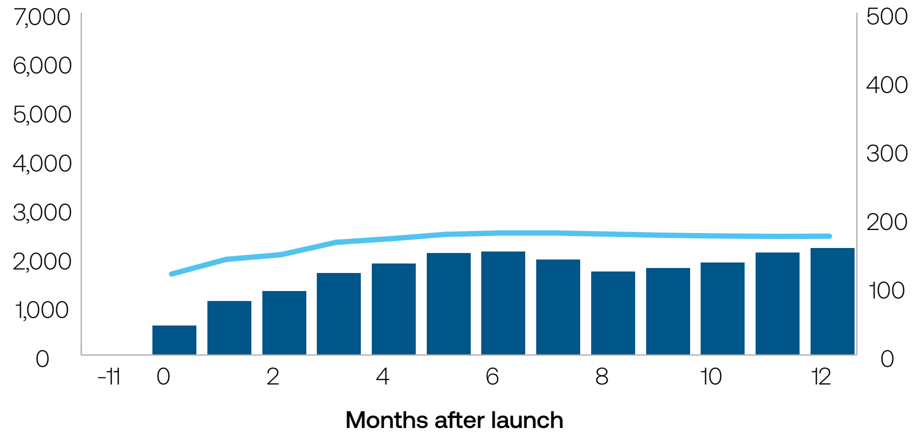
Rokonta



Manowa



Kondembaia



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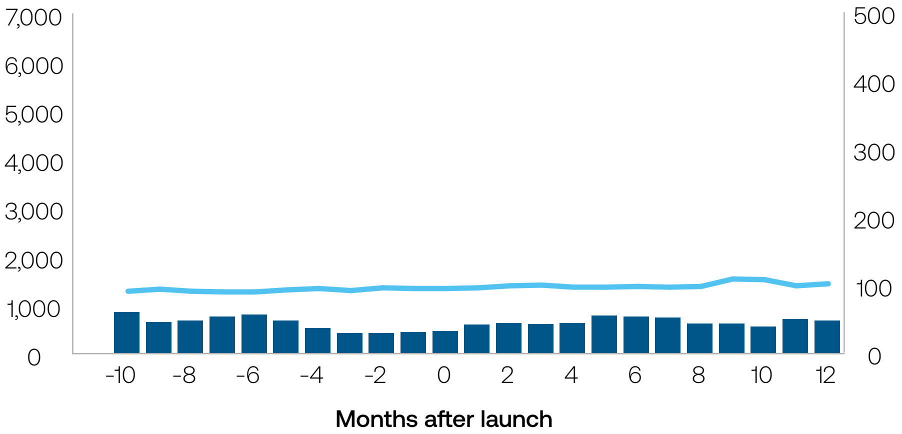
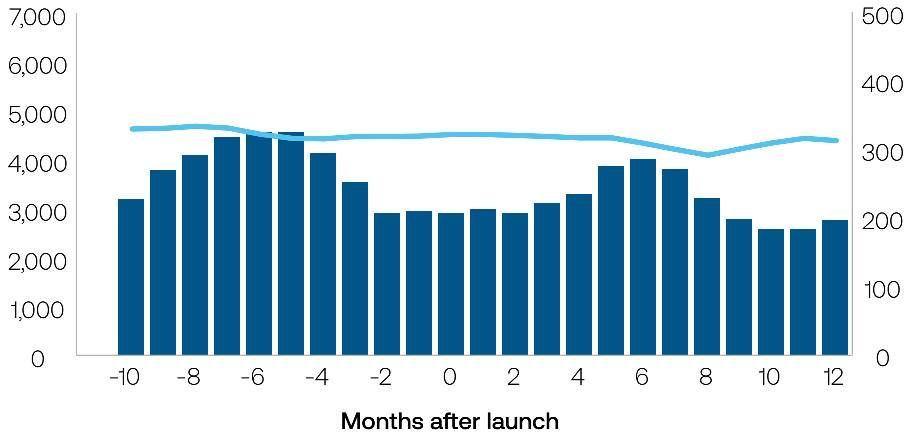
A2: Total consumption and meter count metrics across 9 control sites

Consumption   Meter

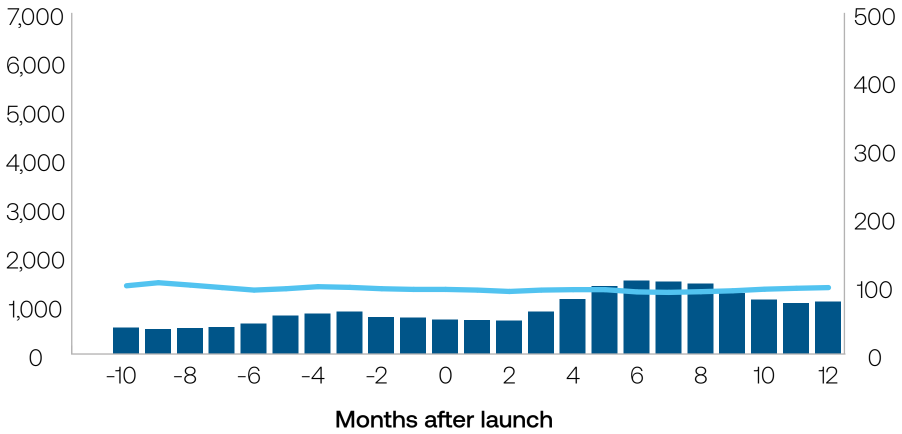
Barmoi Munu



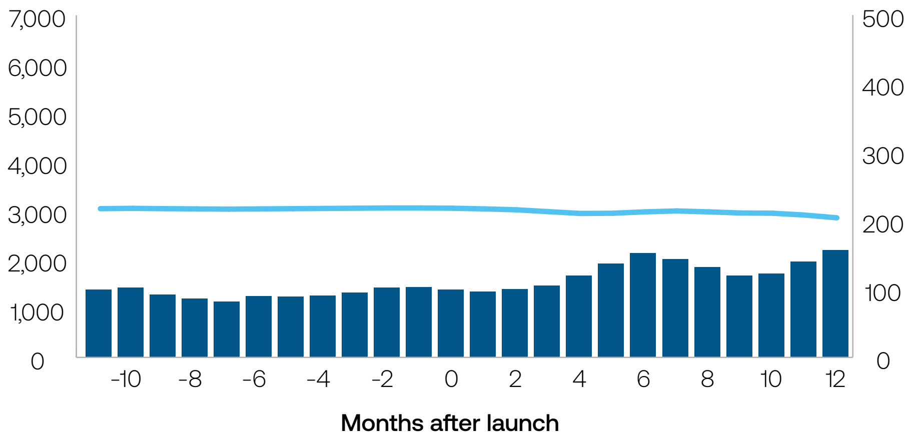
Foredugu



Senehun



Gorahun



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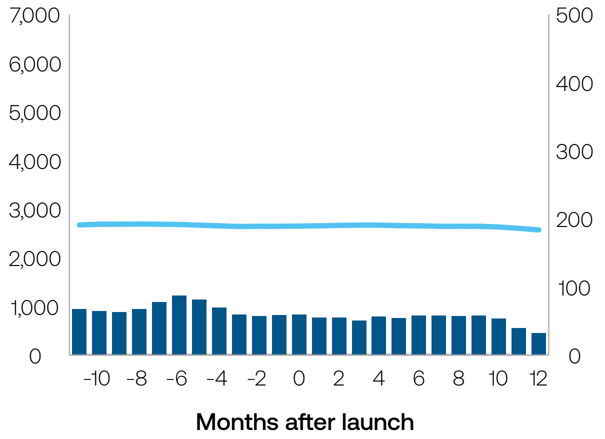
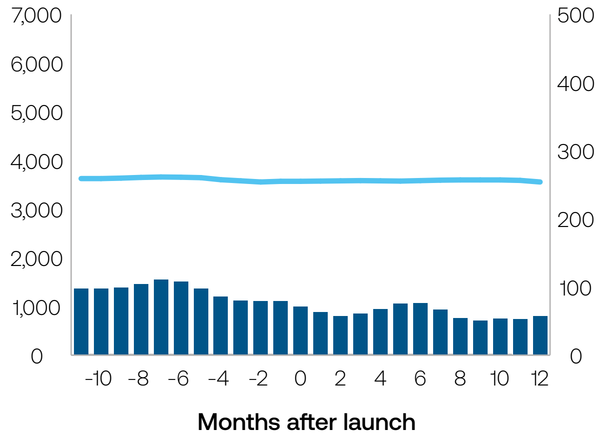
A2: Total consumption and meter count metrics across 9 control sites

■ Consumption ▬ Meter

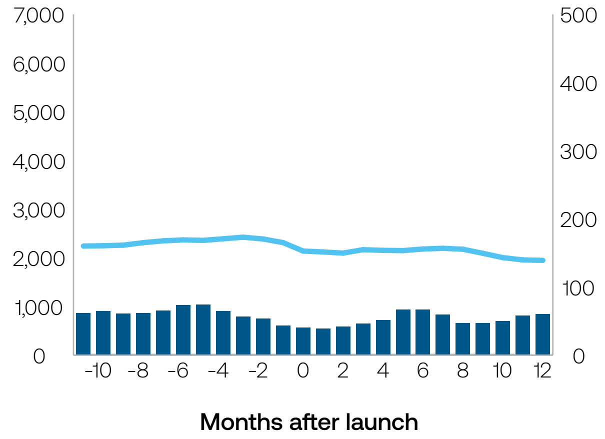
Sandaru



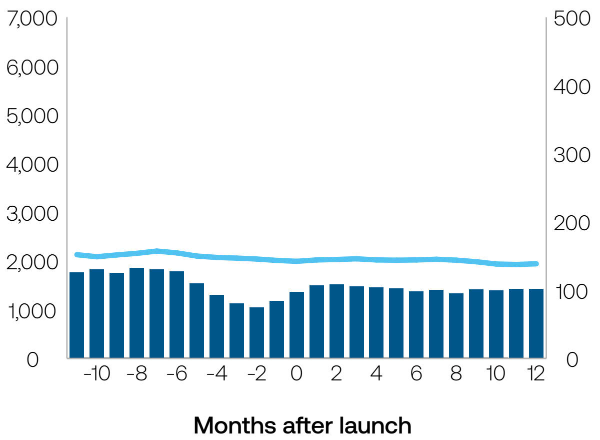
Gandorhun



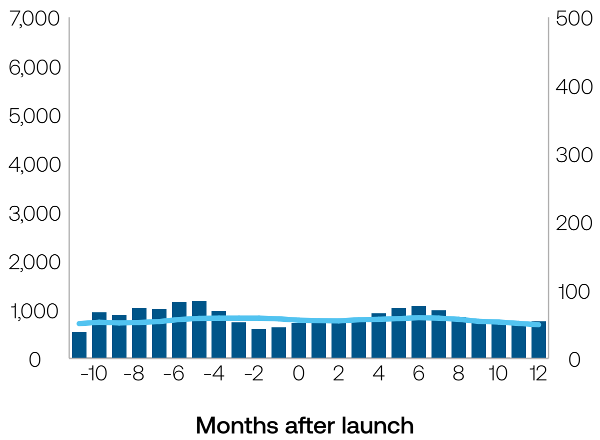
Yiffin



Bafodia



Batkanu



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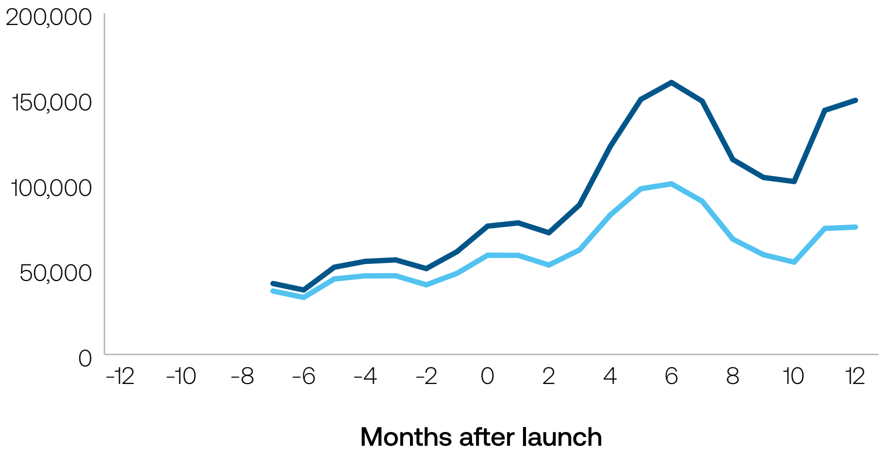
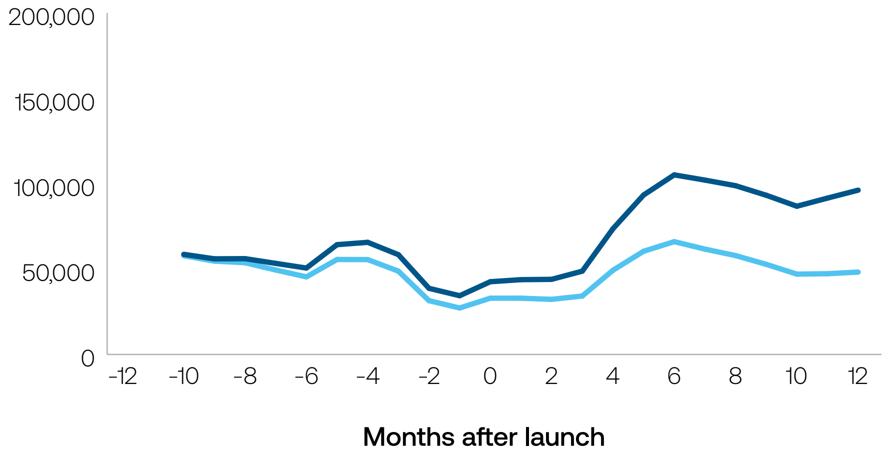
A3: Total revenue (nominal and real) across 8 treatment sites (SLE)

Nominal Real

Rokupr



Conakry Dee



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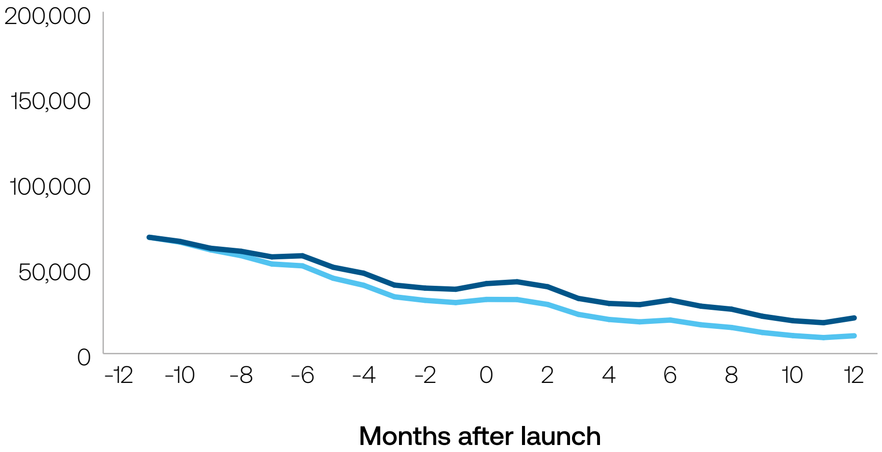
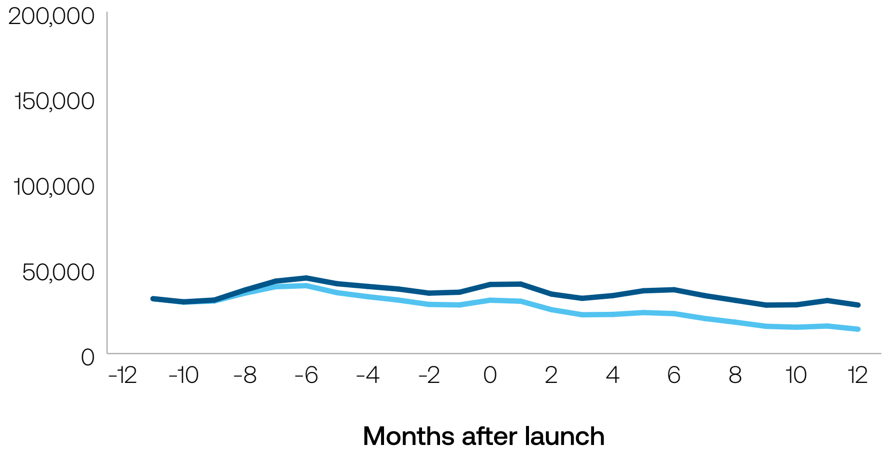


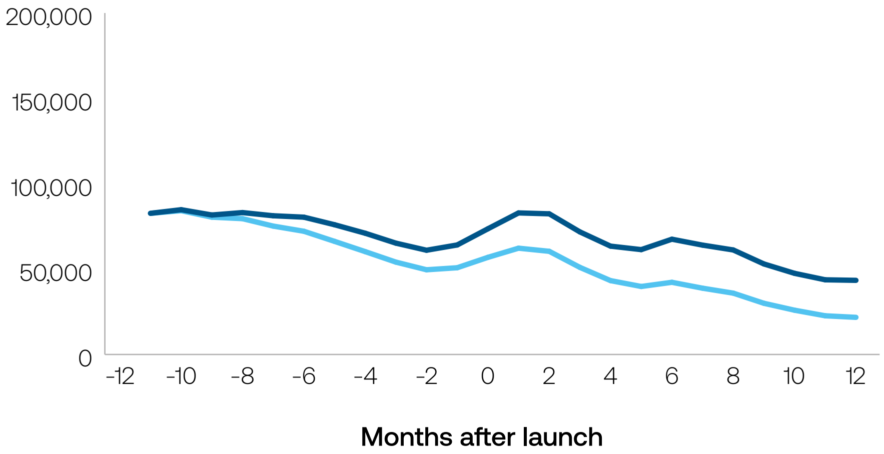
Kayima



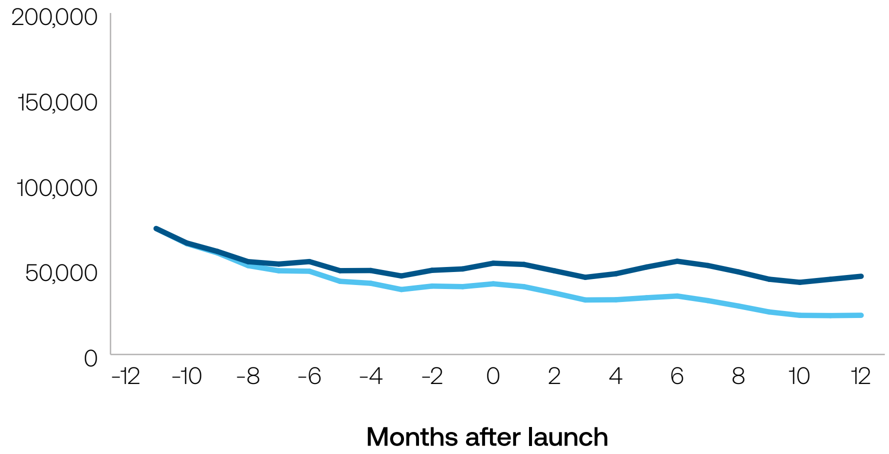
A3: Total revenue (nominal and real) across 8 treatment sites (SLE)

Nominal Real

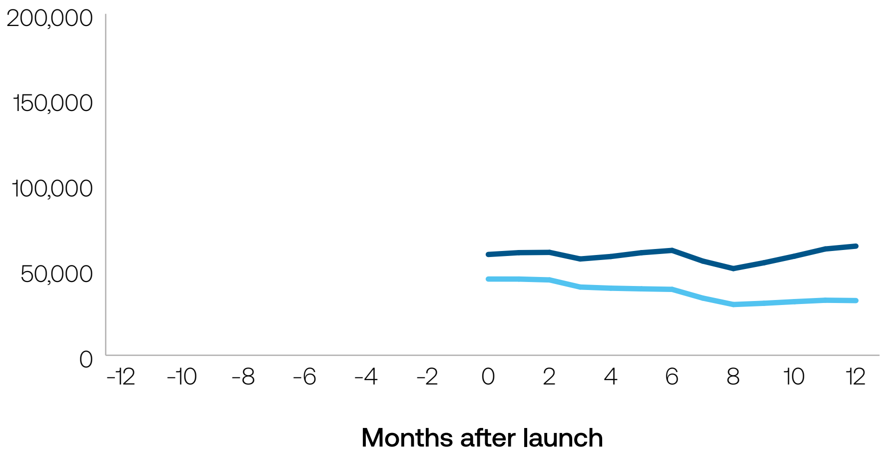
Sulima



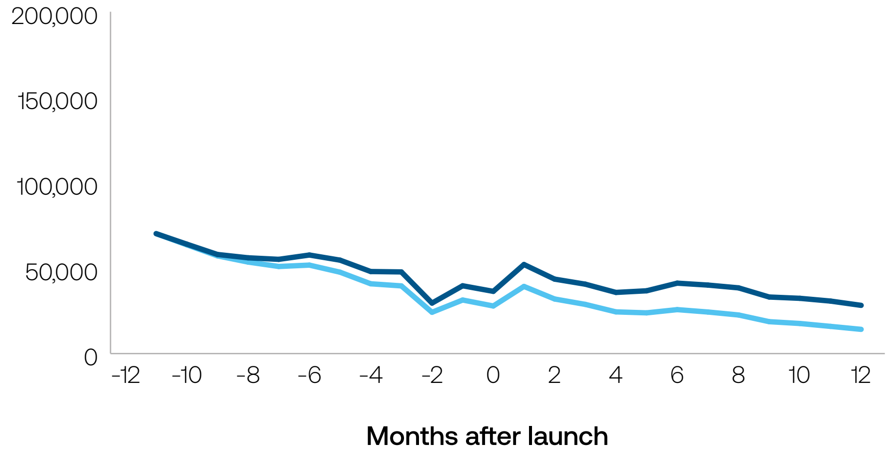
Manowa



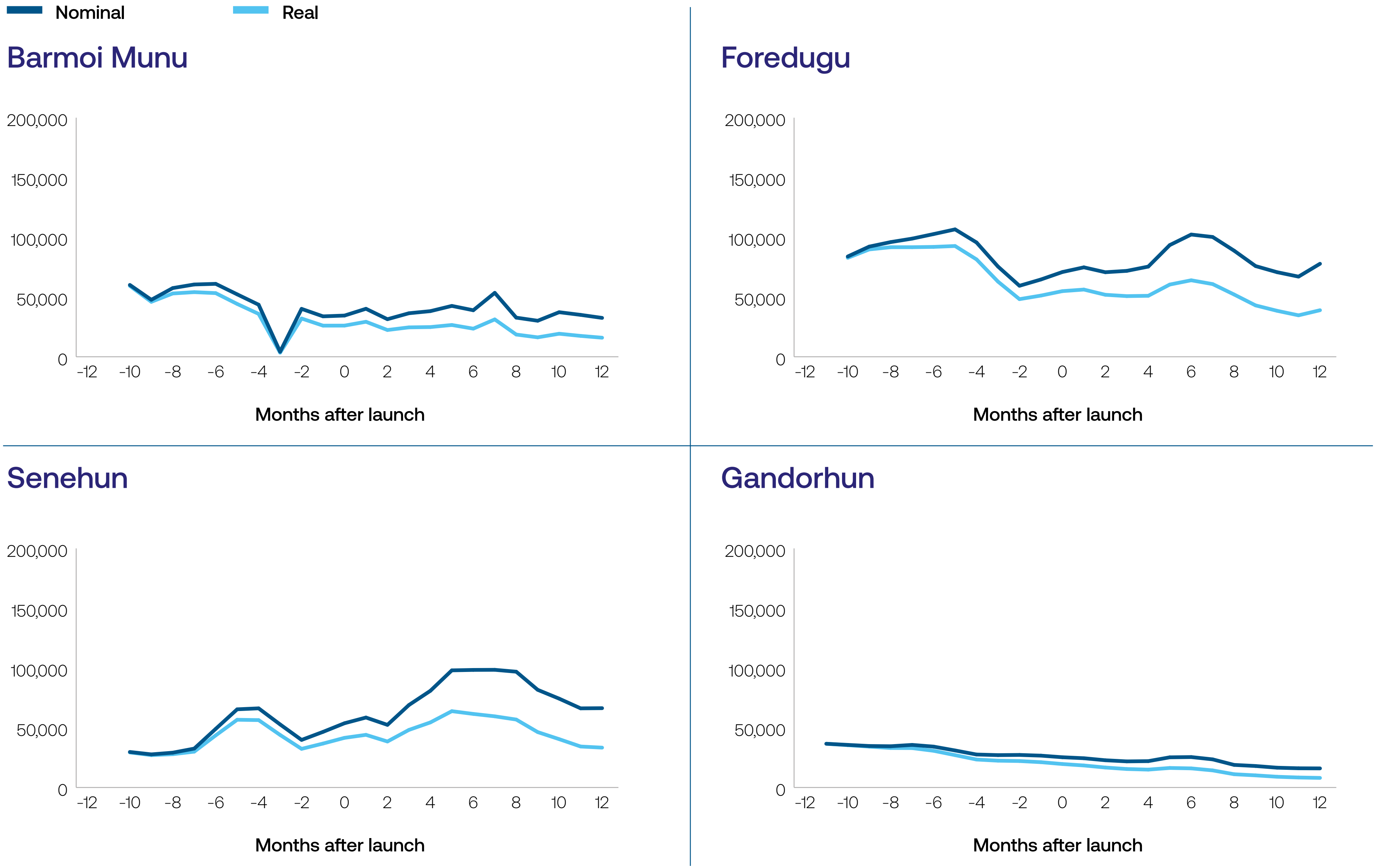
Kondembaia



Rokonta



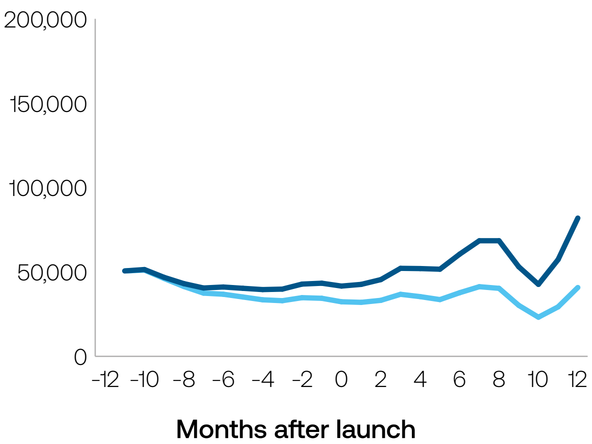
A4: Total revenue (nominal and real) across 9 control sites (SLE)



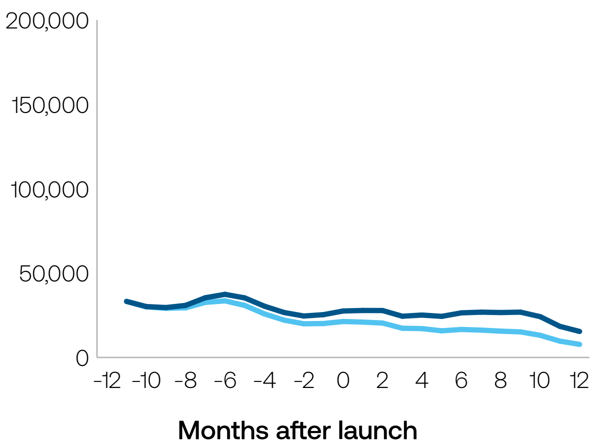
A4: Total revenue (nominal and real) across 9 control sites (SLE)

Nominal   Real

Gorahun



Sandaru



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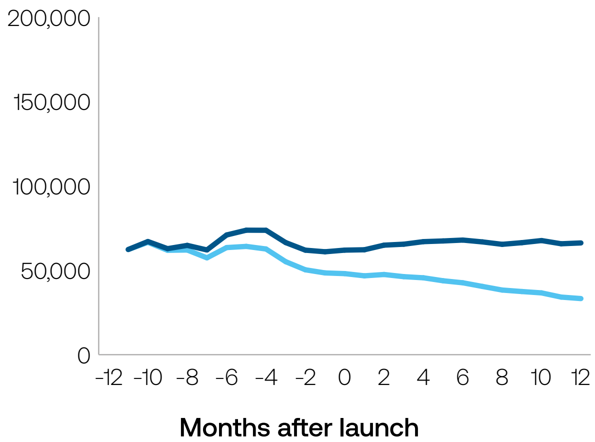

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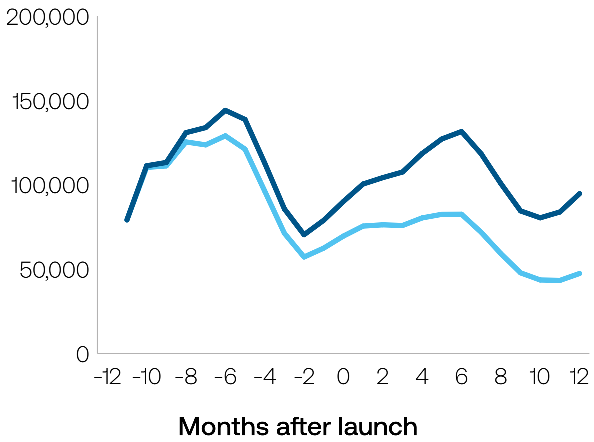

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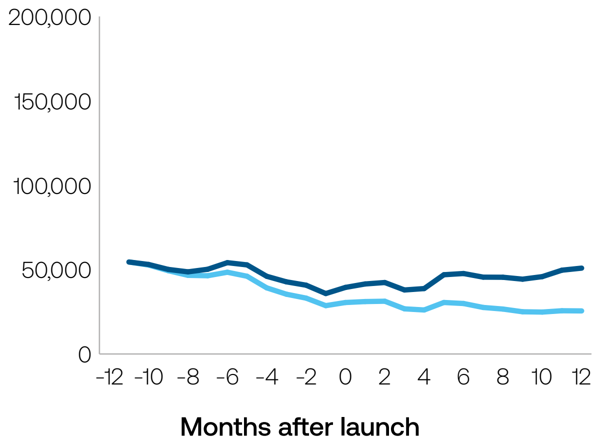
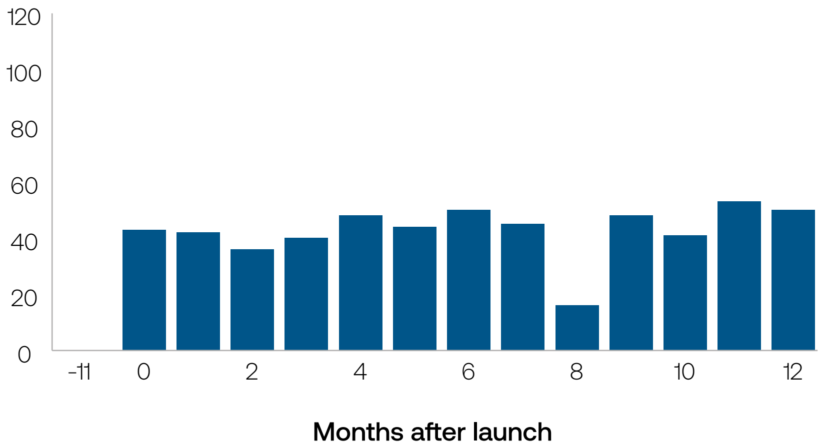


A5: Site utilization across 8 treatment sites (%)

Rokupr



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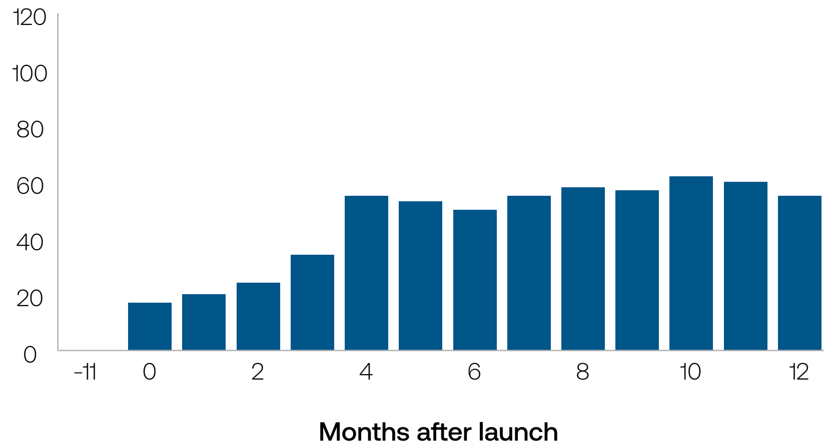
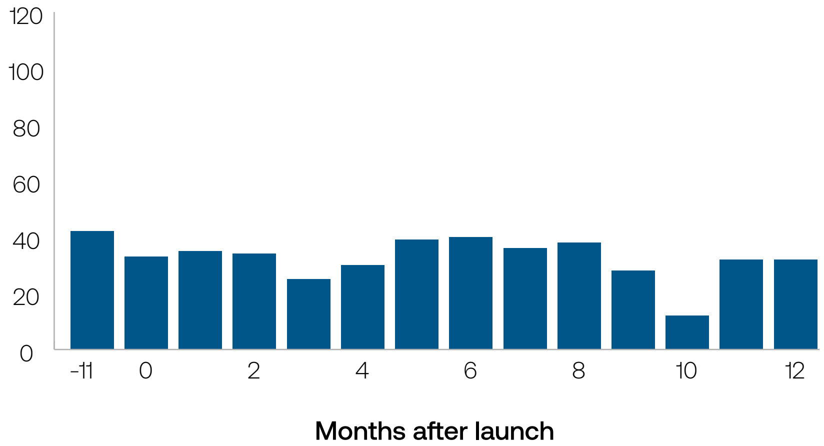


Gbap



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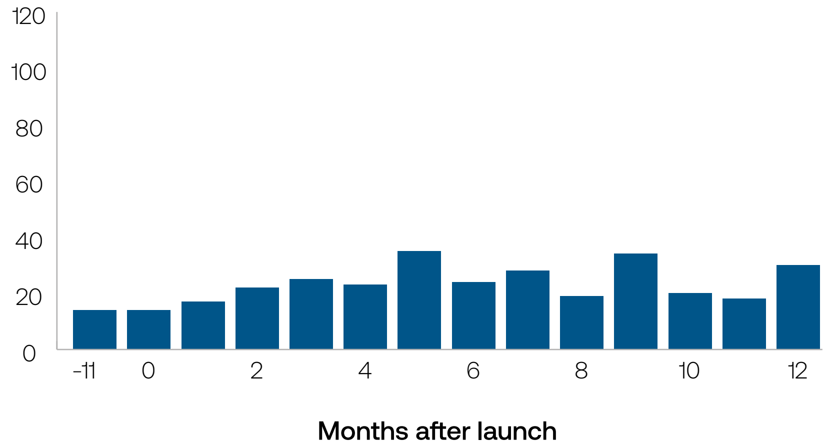
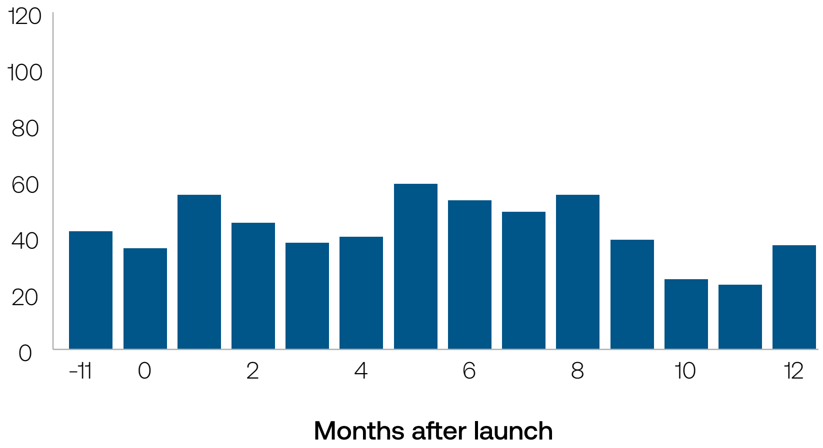


A5: Site utilization across 8 treatment sites (%)

Sulima



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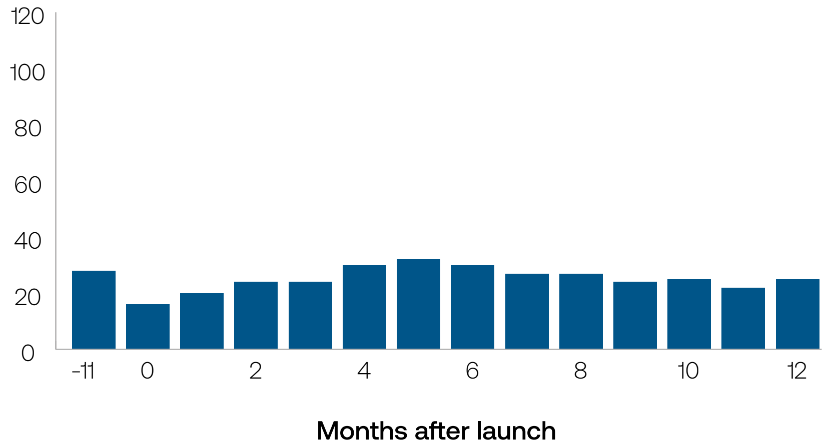
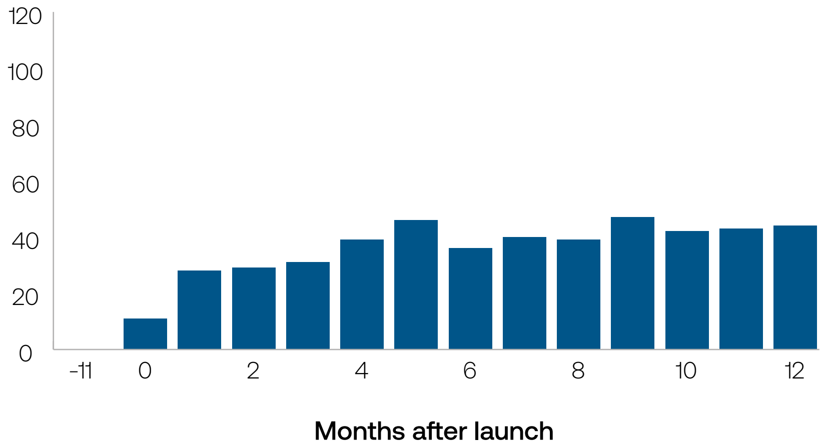
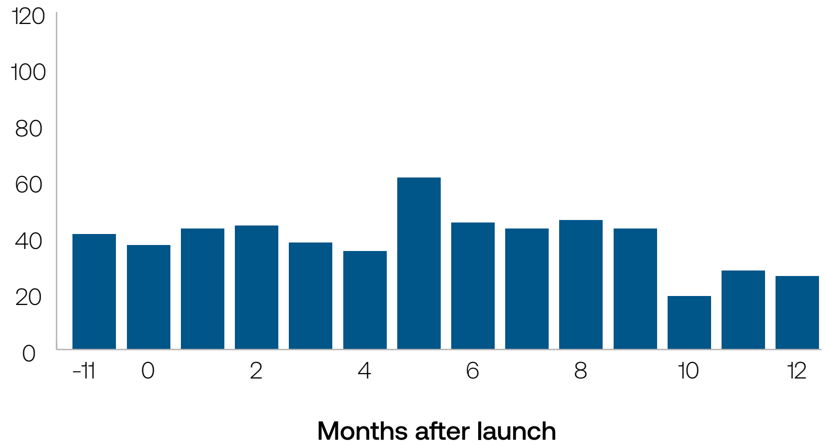


Kondembaia

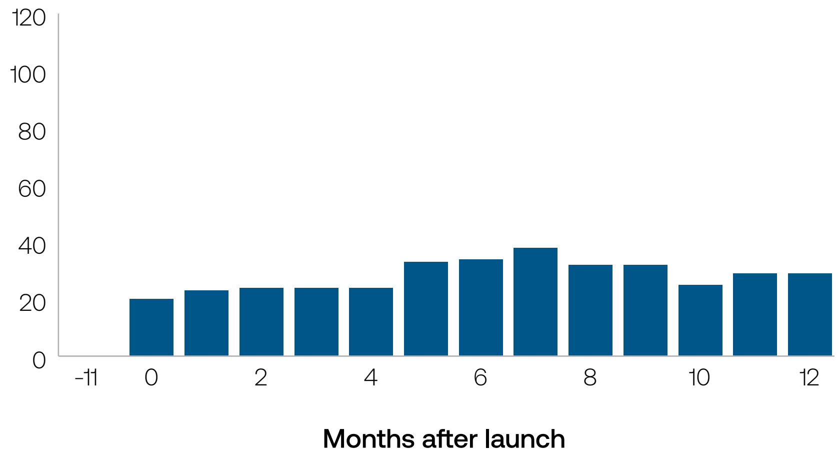


Rokonta

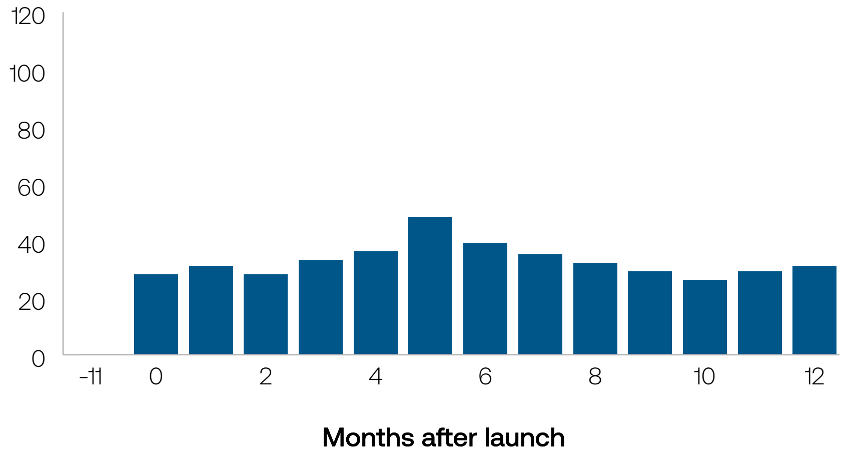


A6: Site utilization across 9 control sites (%)

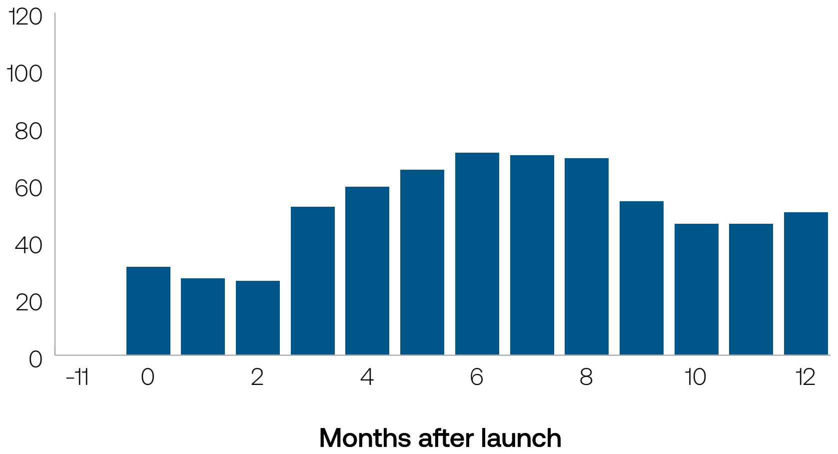
Barmoi Munu



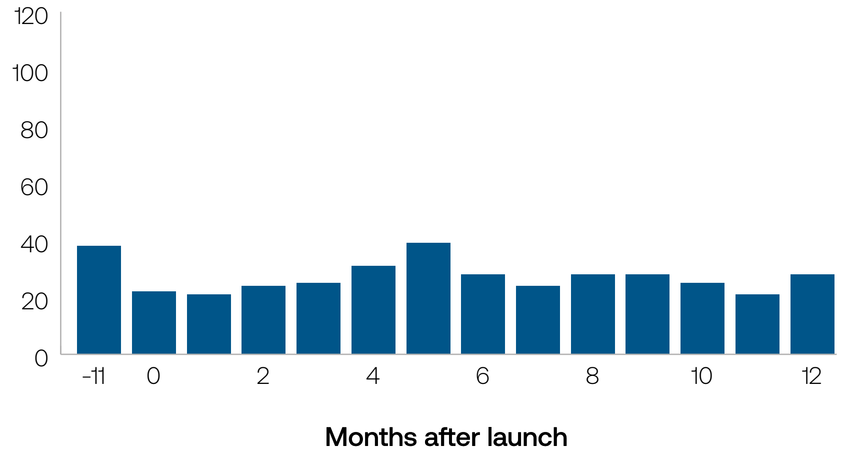
Foredugu



Senehun

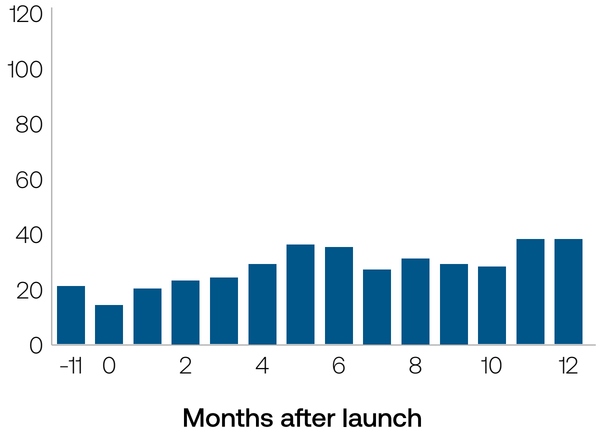


Gandorhun

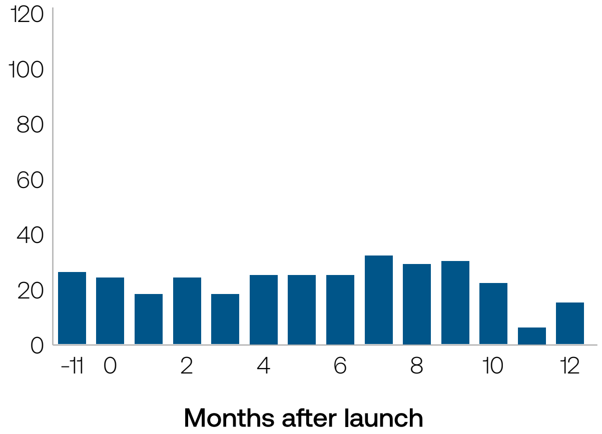


A6: Site utilization across 9 control sites (%)

Gorahun



Sandaru



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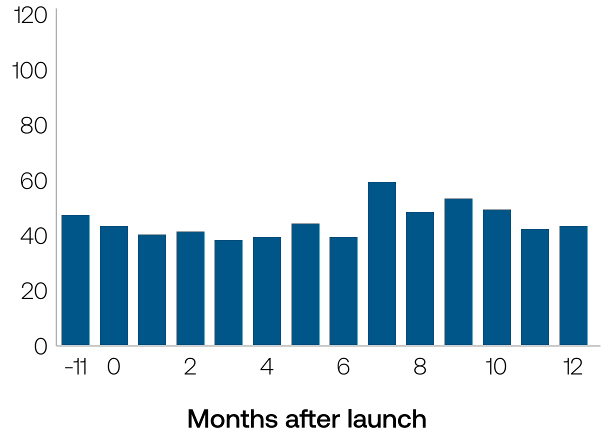
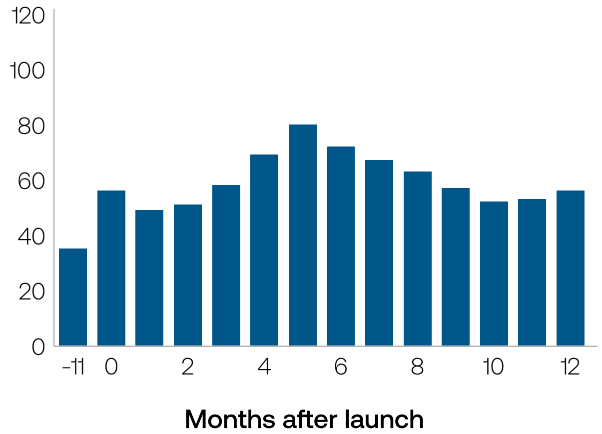
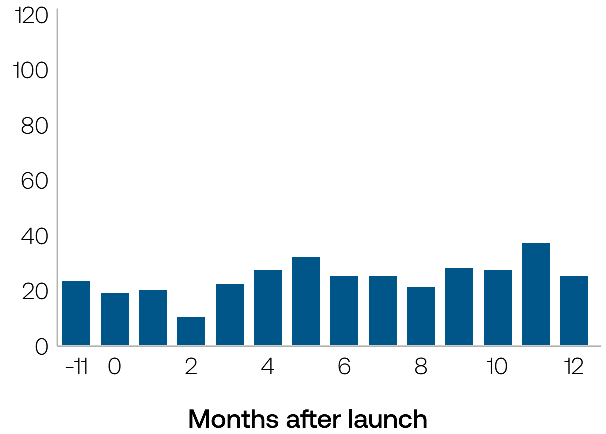


Batkanu

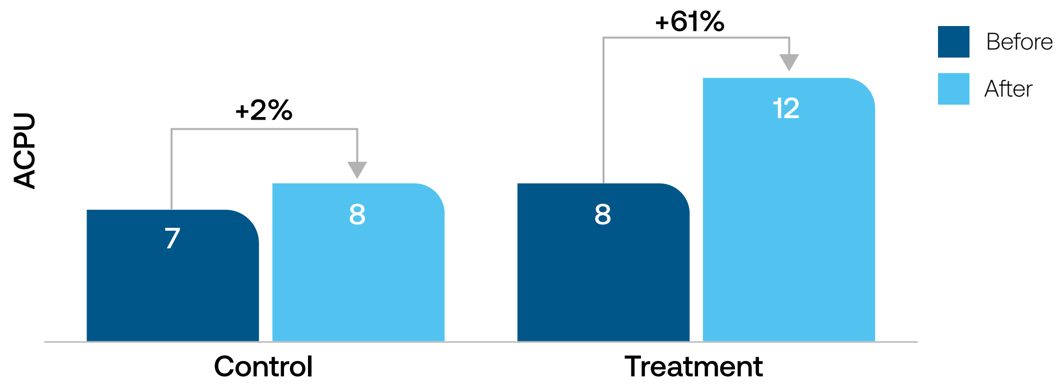


Yiffin

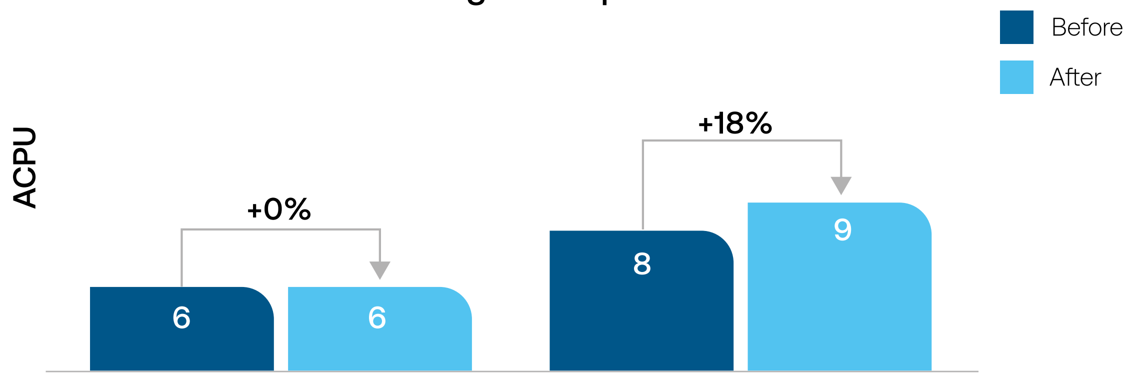


B1: A difference-in-difference analysis shows an increase in ACPU in all treatment sites by 61% compared to a 18% increase when excluding developer[1]

Difference-in-difference analysis across all treatment and control sites



Difference-in-difference analysis across treatment and control sites excluding Developer 1

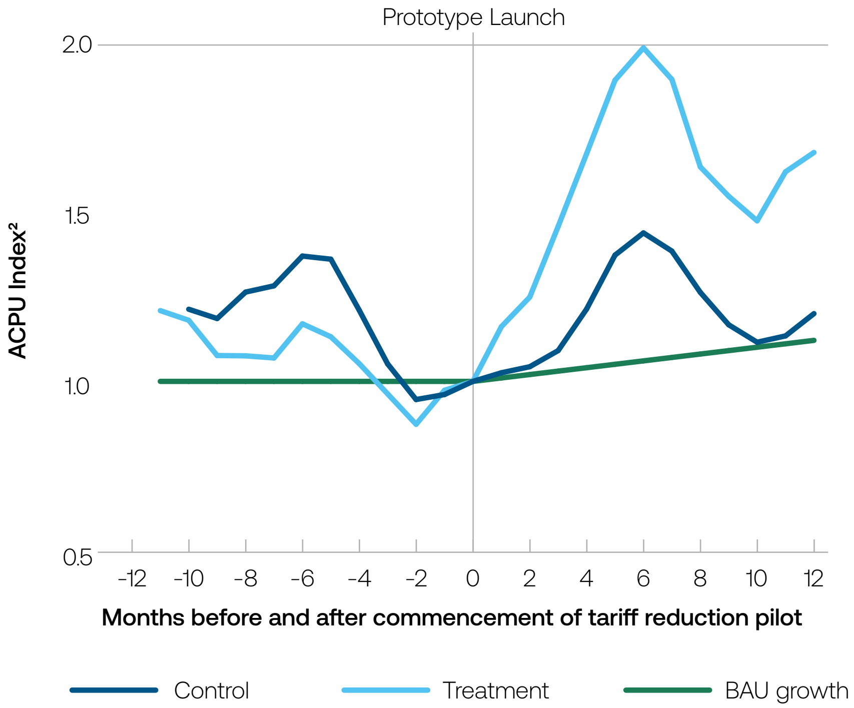


- Difference-in-differences analysis compares the difference in the change over time in ACPU between the treatment and the control group. The difference in difference methodology looks at change in consumption at an individual meter reading as opposed to consolidated and/or averaged data at site level.
- If we take a difference-in-difference analysis1, **treatment sites exhibit a 61% increase in consumption** compared to a 2% increase at control sites.
- **Excluding developer 1, treatment sites experience a 18% increase** compared to a zero % increase at control sites.

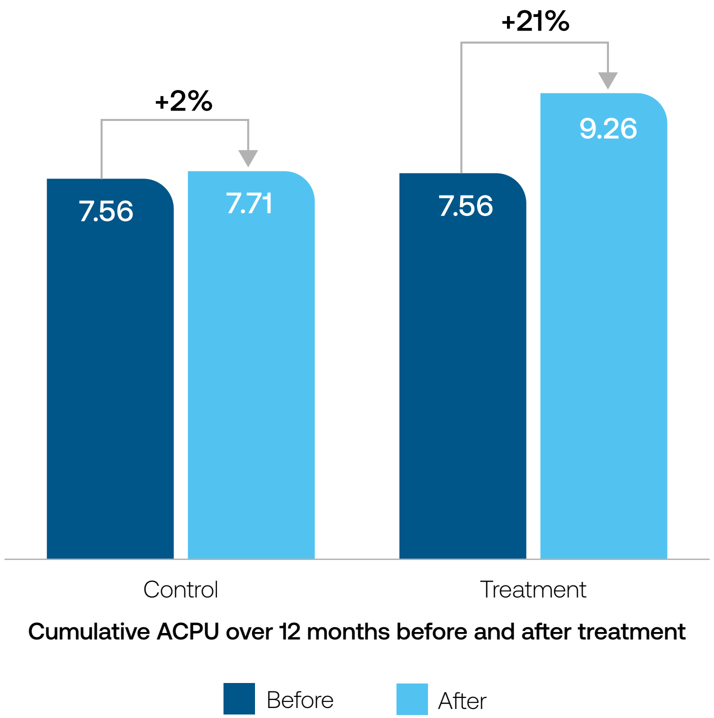
Image: © Adebayo Community

B2: After filtering for both outlier sites and reliability, average ACPU growth on treatment sites increases by 21%

ACPU across treatment and control sites - Filtering for uptime and outlier sites[1]



Average ACPU across all treatment and control sites - Filtering for uptime and outlier sites (kWh)



1. The averages shown on the charts are 3-month moving averages. This is done to smooth out the outliers and uncover the underlying trend.
2. ACPU index is calculated by dividing the average at any month by the average at month 0
Note: Months -11 to 0 denote year 0 of operations, whereas months 1-12 shows year 1 of operations

What we're seeing

After removing outlier sites and filtering for reliability, there was an observable ACPU increase by 21% on treatment sites, compared to 2% on control sites.

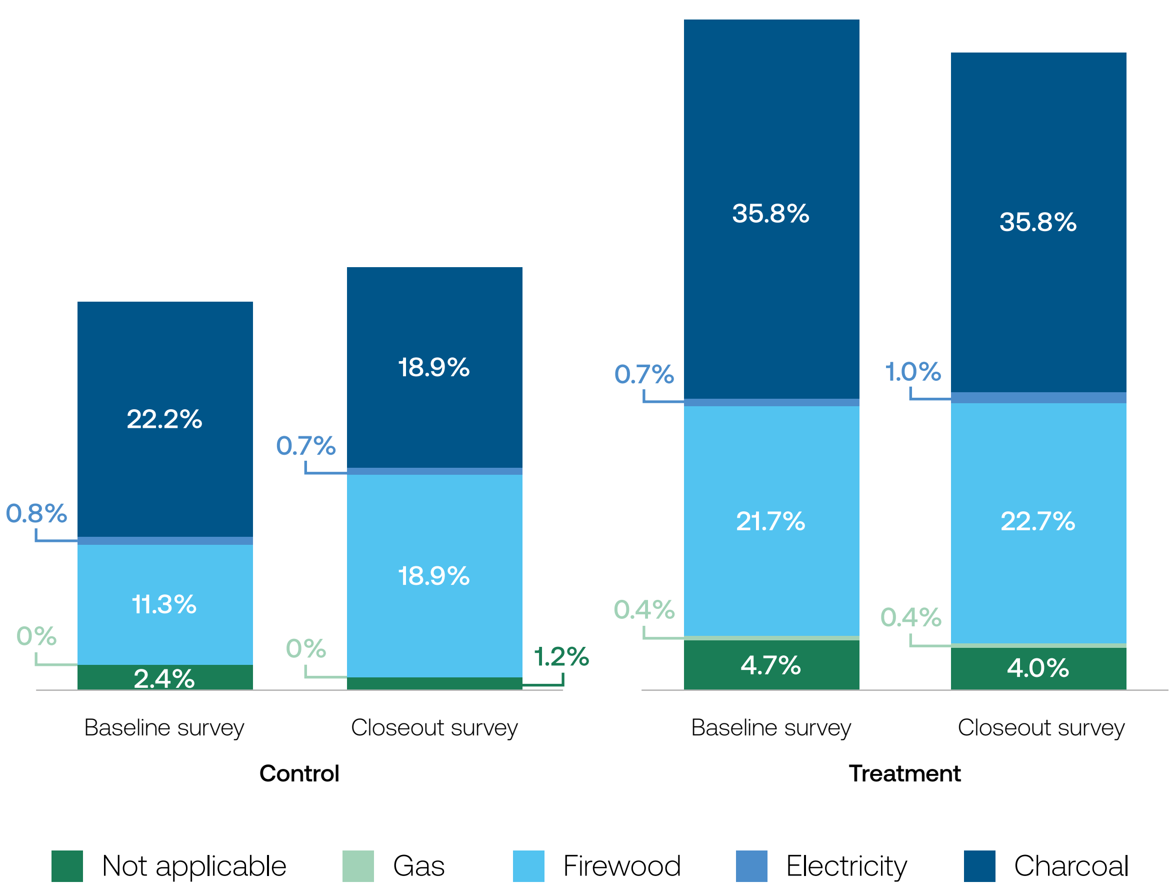
What it means

Uptime positively impacts consumption on both treatment and control sites when excluding Developer 1 sites.

After removing outlier sites, which represent the highest-performing sites, and filtering for uptime/reliability, the analysis show that reliability plays a significant role in boosting consumption mostly in treatment sites.

C1. Case Study: Survey analysis indicate that most minigrid consumers use the minigrid for lighting and powering appliances and very little (1%) of consumers use it for cooking

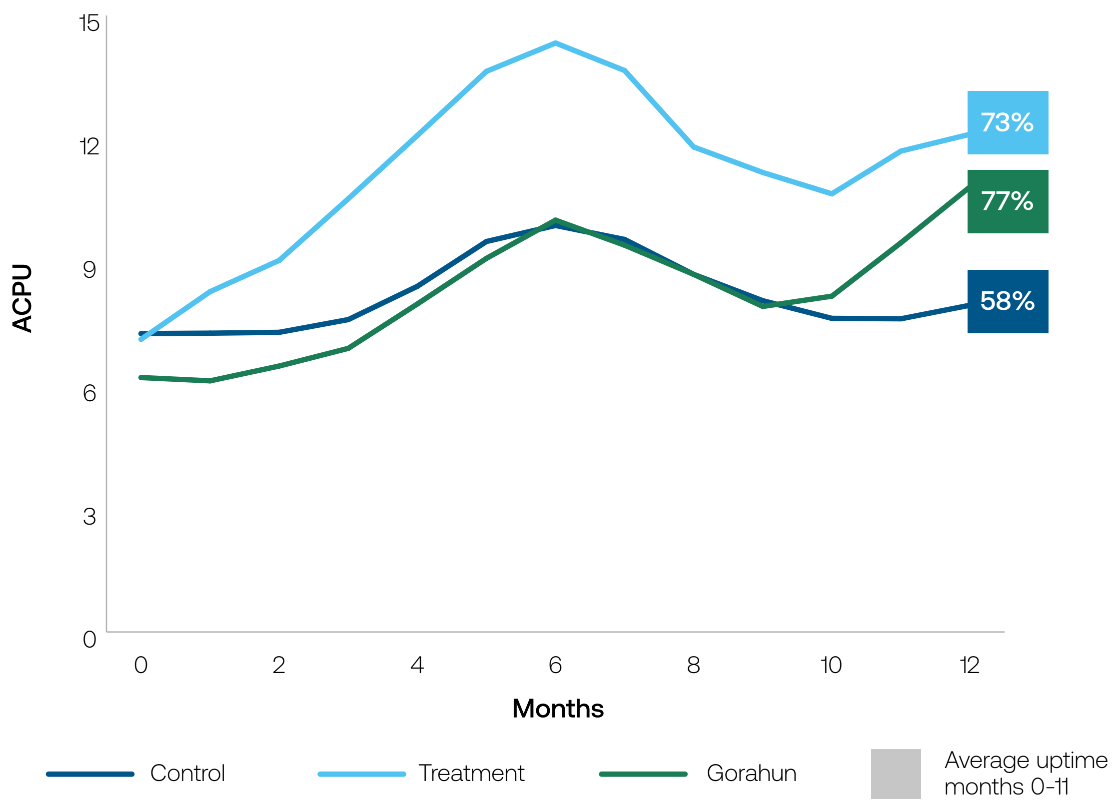
Consumption of different cooking sources as observed in the survey analysis



- From the survey analysis, it is evident that minigrid electricity is primarily used for lighting and powering other appliances, rather than for cooking purposes.
- Overall, the percentage of people using **electricity for cooking the treatment site has increased by 0.3 pp, while the control site experienced a slight decline of 0.1 pp**
- Furthermore, the survey findings indicate a decrease in the usage of charcoal and an increase in the utilization of firewood. This trend could be explained by the prevailing macroeconomic challenges, which may have prompted a shift towards the use of firewood, a free or more affordable natural resource.

C2. Case Study: Even without subsidy, high reliability plays a crucial role in increasing consumption

Average consumption per user (ACPU) across treatment and control sites, and Gorahun (kWh)[1]



- Gorahun is a city in the forested district of Kenam. Gorahun exhibited a higher ACPU than the average across control sites but a lower ACPU nonetheless compared to treatment sites.
- The higher ACPU experienced in Gorahun relative to the average ACPU in control sites is driven by 10 businesses that operate freezers on the grid.
- Consistent electricity supply driven by the presence of new batteries and a functioning generator have provided optimum conditions for consumption
- *Customers in Gorahun have lauded the reliable power, emphasizing its positive impact on their daily lives.*
- These fundings further underline how uptime significantly impacts ACPU even at an unsubsidized tariff, making the case for developers to prioritize consistency and quality of service to their customers.

The averages shown on the charts are 3-month moving averages. This is done to smooth out the outliers and uncover the underlying trend.
ACPU index is calculated by dividing the average at any month by the average at month 0
Months -11 to 0 denote year 0 of operations, whereas months 1-12 shows year 1 of operations
Average uptime for control sites excludes Gorahun

D1: Cost Reflective Tariff

The cost reflective tariff indicates existing subsidies are insufficient to meet desired investor returns.

The cost-reflective tariff is calculated by dividing the developer's operational expenditure (OPEX) and capital expenditure (CAPEX) by the consumption or kilowatt-hour (kWh) demand. This resulting figure typically exceeds the tariff that developers charge their consumers.

To address this discrepancy and lower the tariff, developers in Sierra Leone seek grants or results-based financing (RBF) options to subsidize the CapEx, thereby reducing the cost-reflective tariff.

$$\text{Cost reflective tariff} = \frac{(\text{OPEX} + \text{CAPEX})\ (\$)}{\text{Consumption (kWh)}}$$

The cost-reflective tariff in Sierra Leone currently ranges between SLE 18. - SLE 35 across the developers, more than 4x the current proposed tariff under the tariff reduction plan and more than 2x the average base tariff of SLE 7.527.

Currently, even at the average base tariff of SLE 7.527, developers struggle to meet investor returns without some form of additional subsidy.

Image: Pexels/Kelly

The subsidized tariff was established through elasticity modeling, incorporating a minimum rate to cover developer expenses and considering long-term subsidy viability

The subsidised tariff was calculated under the following principles:

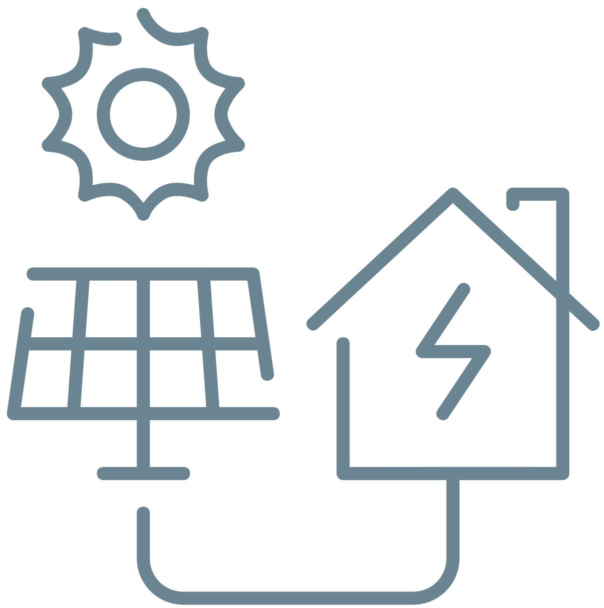
a) The subsidy intervention should allow the Operators to maintain their project's baseline IRR

b) The same tariff should be applied for residential and productive use, with a standard standing charge across all

c) The mini-grid customers should experience subsidized tariff for the duration of the minigrid lifetime (~20 years)

To determine the subsidized tariff, we modeled various reduction scenarios, each with assumed demand elasticities. For tariffs between US$ 0.35/kWh and US$ 0.5/kWh (elasticity range 0.8-1.0), we projected that consumption would increase enough to cover the mini-grid's lifetime cash flows.

We set a minimum tariff of US$ 0.42/kWh to ensure developers could cover operating and maintenance costs. The final subsidized tariff was set at US$ 0.46/kWh (4,439 Sierra Leonean Leones at the time).



The three disbursements components:

The pilot disbursements account for devaluation effect during the one-year pilot period (exchange rates moved from ~SLE 9.65 per $ to ~SLE 13.06 per $). The subsidy paid per developer is a sum of three (3) disbursement components below:

a) Consumption subsidy: is the product of actual consumption (in kWh) on pilot treatment sites, and the pilot consumption subsidy (24c/kWh)

Consumption subsidy amount (USD) = consumption (kWh) * subsidy: 24 c/k kWh

b) Consumption devaluation subsidy: due to subsequent currency devaluation ~20 cents/kWh, we introduced an additional 'devaluation subsidy' to maintain the intended tariff level and match operator's IRR.

Consumption devaluation subsidy amount (USD) = consumption (kWh) * subsidy: ~20 c/k kWh

c) Standing charge devaluation subsidy: Also due to currency devaluation, standing charge was only effectively ~0.85 cents/connection/month, compared to ~$1.15/connection/month. In line with program principle, the lab covered ~40 cents/connection/month differential for the duration of the 1-year pilot and addressed post-pilot devaluation (year 2-5) in the scale-up budget.

Standing charge devaluation subsidy amount (US$ / month) = Number of connections * subsidy: ~40 cts/connection