CROSSBOUNDARY

ENERGY4IMPACT

ACCELERATING ACCESS TO ENERGY

Innovation Insight: The Price Elasticity of Power

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II. Introduction: The Mini-Grid Innovation Lab is launching an Innovation Insight series

The Innovation Lab tests innovations that improve the mini-grid business model

CrossBoundary launched the Mini-Grid Innovation Lab in 2018 with support from The Rockefeller Foundation. The Lab is supported by Energy 4 Impact, who is responsible for ensuring charitable intent and monitoring social impact, and by the University of Massachusetts Amherst, Carnegie Mellon University, and Duke University, who support experiment design and analysis of results. The Lab prototypes and tests innovations that help mini-grids in Africa provide more power, to more people, at lower cost.

The Lab shares evidence with developers, governments, and funders so they can scale the successful innovation prototypes

The Lab works closely with mini-grid developers to test and identify innovative prototypes that improve the business model, and our work and the results presented here are strongly endorsed by the African Mini-Grid Developer Association (AMDA). Once proven, the Lab works with partners – developers, government, and funders -- to scale the prototypes across other developers and markets. The Lab shares evidence on successful prototypes' impact on the business model to inform how partners can best support it to scale.

The Lab is launching an Innovation Insight series to provide early, actionable business intelligence on initial results from its prototypes

The Lab's Innovation Insight series will provide ongoing, early insights on the prototypes so mini-grid 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, Duke University, and Carnegie Mellon University to publish academic papers on certain prototypes.

III. Executive Summary: reducing tariffs unlocks a significant, pent-up demand for electricity from rural mini-grid customers

Mini-grids are self-sufficient electricity grids that serve households and businesses isolated from or integrated with the main grid. The Mini-Grid Innovation Lab estimates they are the cheapest way to deliver power to at least 100 million Africans. However, rural mini-grid customers typically pay much higher electricity tariffs (price), and consume much less energy, than rural main grid customers. Private rural mini-grid companies must charge their customers tariffs that reflect the full costs of providing power. Public utility-run main grid rural customers typically pay much lower tariffs as their cost of power is subsidized by the utility's higher consuming urban or industrial customers.

The electricity tariff (price) is therefore one of the major drivers of the mini-grid business model, for both the mini-grid operator and the customer. The price of electricity directly determines a mini-grid's revenues, and how much energy a customer can afford to consume. If the price is too high, customers can't afford to buy enough power. If the price is too low, mini-grids sell power below their cost of delivering energy, harming the commercial viability of the project.

Setting the right tariff is an important business model decision for a mini-grid developer. It is a delicate balance between customer needs, developer economics, and the requirements of the regulator. To help mini-grid developers get this decision right, the Innovation Lab is running a Tariff prototype to test the impact of reducing the tariff on the mini-grid business model.

Early results from the Lab's Tariff prototype show that rural mini-grid customers are extremely price sensitive – they are ready to consume much more power than they can afford at current tariffs. In May and June of 2018, the Innovation Lab supported two mini-grid developers in Tanzania to significantly reduce their cost-reflective tariffs on two small, rural sites – by 50% on one site and 75% on the other.

Customers reacted immediately. For every dollar they saved on price, they spent $0.93 on *increasing their energy consumption*. Therefore, despite massive price reductions, developers saw revenues fall by only 7%.

We can make two significant observations from this initial data:

1. Reducing tariffs has an immediate and strong effect on rural customers' use of energy. *Rural customers are budget constrained.*
2. Mini-grid developers may be able to charge lower tariffs and achieve the same or similar revenue.

However, *consumption is not free*. It requires investment in generation and storage, which means added costs to serve the increased demand. A tariff that is too low could be below the levelized cost of energy of the system. We therefore don't know how lowering tariffs impacts

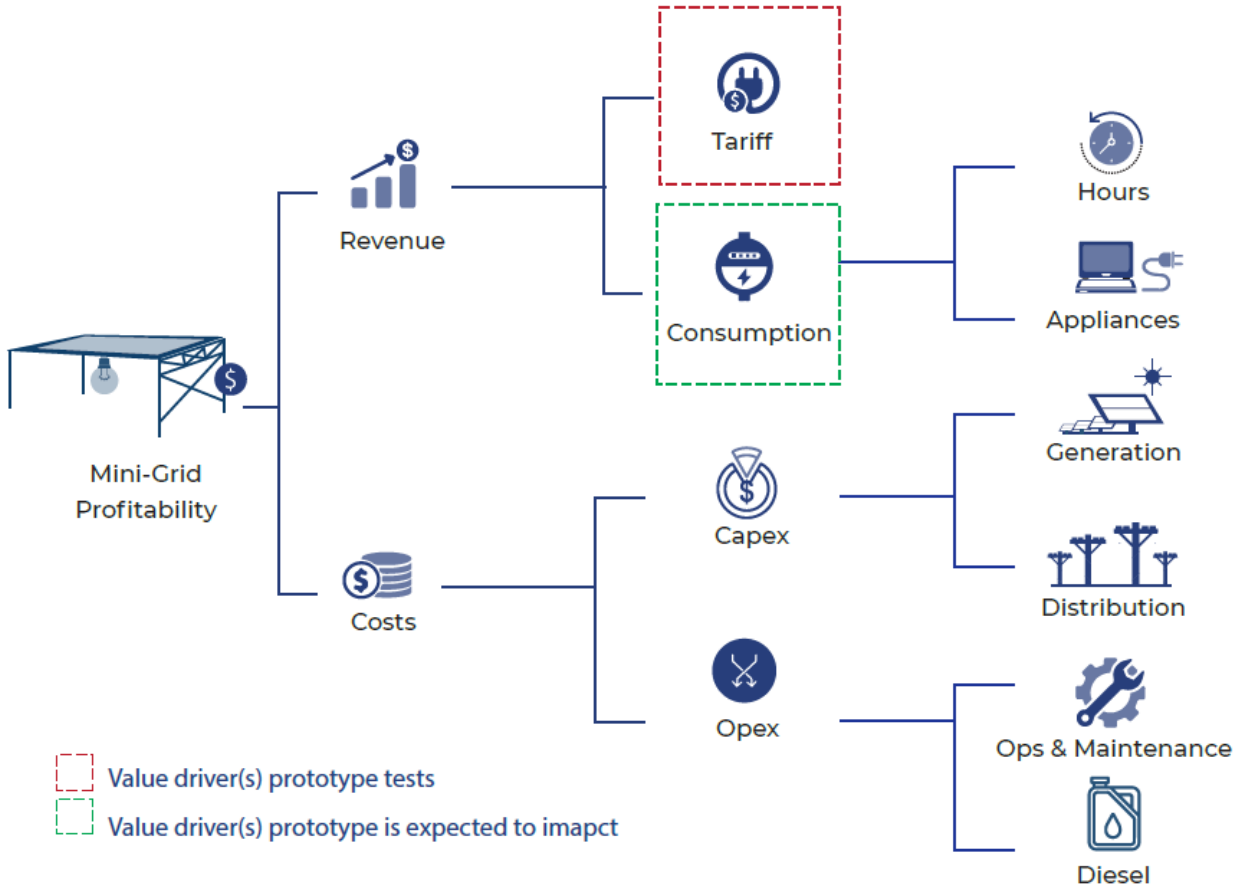
the business model until we have a complete picture of the associated costs. The Lab will present this analysis in the next release of this paper. While the initial results are promising, neither developer could have reduced their tariffs without funding support from the Lab in the form of a tariff subsidy.

It's important to emphasize that this initial data represents actionable intelligence rather than scientific evidence. The data sets are small (128 customers across two sites), customers at both sites are low consumers relative to other mini-grid customers, and the prototype is only nine months into its five-year life. These are preliminary results and may change with more data over time, or more data from additional sites and from other markets. However, the Lab will soon add a third site, bringing total connections under the prototype to 332. The Lab is working with mini-grid developers and funders to further prove the level of tariff reduction that will fully unlock customer demand. The Lab will test tariff reductions on sites in new countries in Africa, with different types of customers, different tariff structures, and different grid sizes.

IV. Why we're doing this: tariff is a major driver of both mini-grid revenue, and how much energy customers can afford

The Tariff prototype tests the impact of reducing the **tariff** on the mini-grid business model. The Lab expects reducing the tariff will impact electricity **consumption**, either because customers can afford to use energy in new ways (**appliances**) or they can afford to use energy for longer, whether in the same or new forms (**hours**).

The Tariff prototype tests the impact of reducing tariffs on electricity consumption



V. How we're doing it: subsidizing developers to reduce the tariff

To test this prototype, the Lab provided a subsidy that allowed developers to reduce tariffs at two mini-grid sites in Tanzania. At one site, with 63 total connections, the Lab reduced the tariff by 50%. At the other, with 65 total connections, the Lab reduced the tariff by 75%. The tariff reductions were chosen so the price change was significant enough to change customer behavior, while mini-grid operators were able to recover enough of their costs to ensure their sustainability of their business model.

After community engagement, the mini-grid developers implemented the reductions on a single day, dropping the price per kWh of power offered to all customers on site by 50% and 75%, respectively. The Lab collected consumption and payment data from each site on a monthly basis, and conducted two customer surveys to collect demographic, socioeconomic, and user experience data.

More details on study methodology can be found in the Study Design, which will be available on CrossBoundary's website.

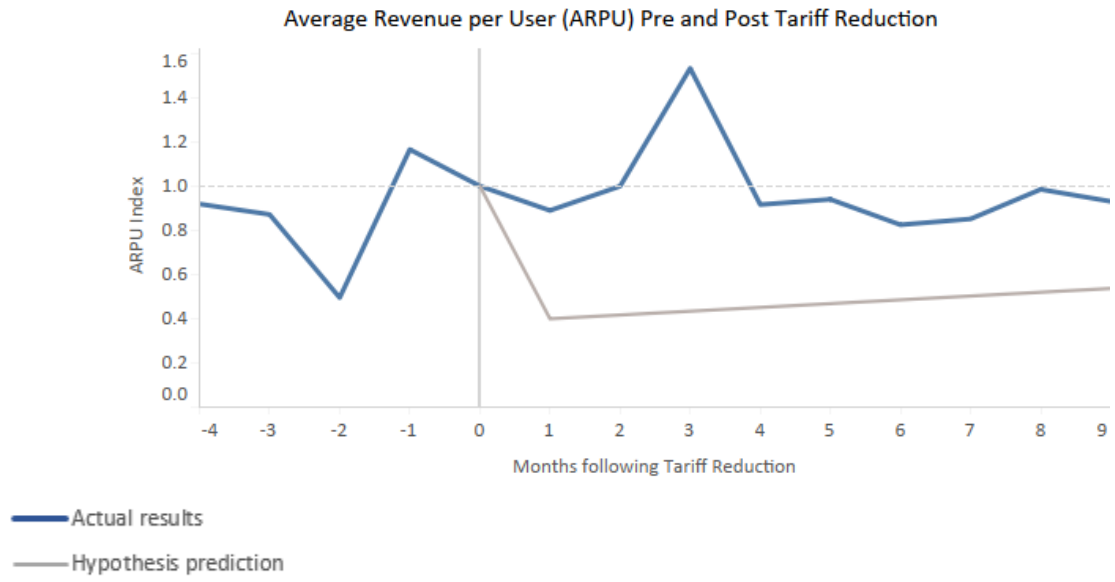
VI. What we're seeing: mini-grid customers immediately increased their consumption following the tariff reduction

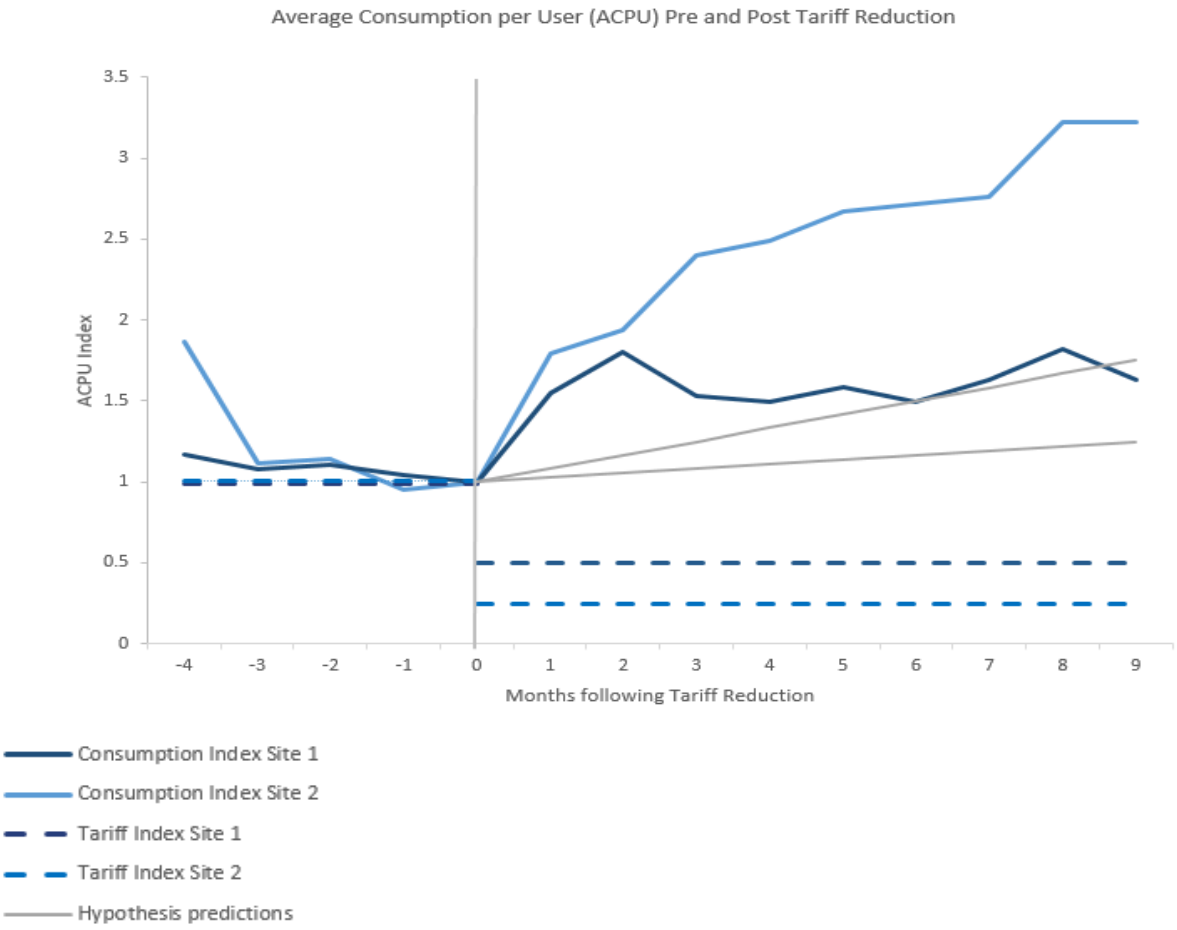
The Lab made five hypotheses on how we expected the prototype to impact the mini-grid business model. The following outlines, for each hypothesis: what we expected to see, what we're seeing, and what it means. The fifth hypothesis, which addresses the prototype's social impact, will be included in the final white paper published for this prototype. Customer surveys are conducted to collect customer-level data on spending, employment, and energy use, among other socio-economic metrics.

Note: Actual values immediately prior to tariff reduction indexed to 1.

Note: Revenues are always aggregated through an average, as ARPU is a common metric for mini-grid developers. Most consumption figures shown are aggregated through a median to provide a different perspective of the data. Axes marked by month reflect totals at the end of each month; axes marked by day reflect totals at the end of each day.

Hypothesis 1: Average revenue per user (ARPU), excluding revenues from subsidy payments, will return to pre-treatment levels by year three.



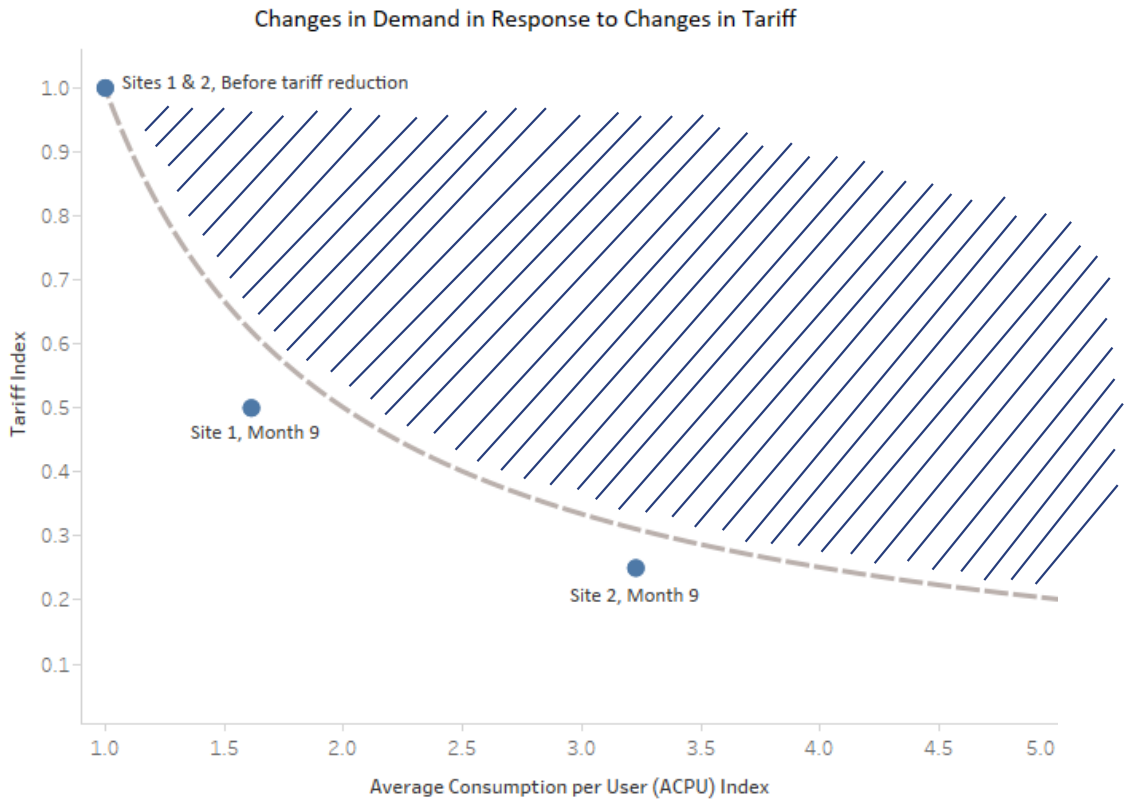


What we expected: After significantly reducing the tariff, revenues fall significantly as consumption remains largely the same. Over the course of three years, customers find more uses for energy and fully utilize the price savings to consume more energy.

What we're seeing: Instead, customers *immediately* used the price savings to consume more energy, increasing total site consumption to 1.6 and 3.2 times original levels, respectively per site, by month nine. The customers who increased their consumption the most typically did so on higher tariffs, whether due to their consumption tier or the time of day they used energy. Every kWh they consumed generated a higher than average revenue contribution. Therefore, the increase in the ARPU index outpaced the increase in the average consumption index, and developer revenues are at 93% of pre-treatment levels after nine months.

What it means: Rural mini-grid customers have a much greater demand for electricity than they can afford at cost-reflective tariffs. Mini-grids may be able to reduce tariffs and achieve the same ARPUs. Where the reduced tariff is lower than the mini-grid's levelized cost of energy (LCOE), a subsidy will be required.

Hypothesis 2: A reduction in tariff will drive a proportionally larger increase in consumption over five years, thereby increasing revenues.[1]



This shaded area represents increased revenues, in line with our hypothesis. Customers use every dollar they save, and more, to increase their consumption.

This line represents constant revenue. Customers use every dollar they save to increase their consumption.

What we expected: Lower tariffs allow customers to move up the energy ladder in appliance use, from lights to TVs, from TVs to freezers, and so on up the energy ladder. As customers incorporate these higher-energy appliances into their lives over five years, they fund an increased electricity budget through either increased income from the appliances (e.g. selling cold drinks from a freezer) or displaced spending on other uses (e.g. kerosene for lighting).

What we're seeing: Electricity spending is 7% lower across both sites, nine months into the five-year trial.

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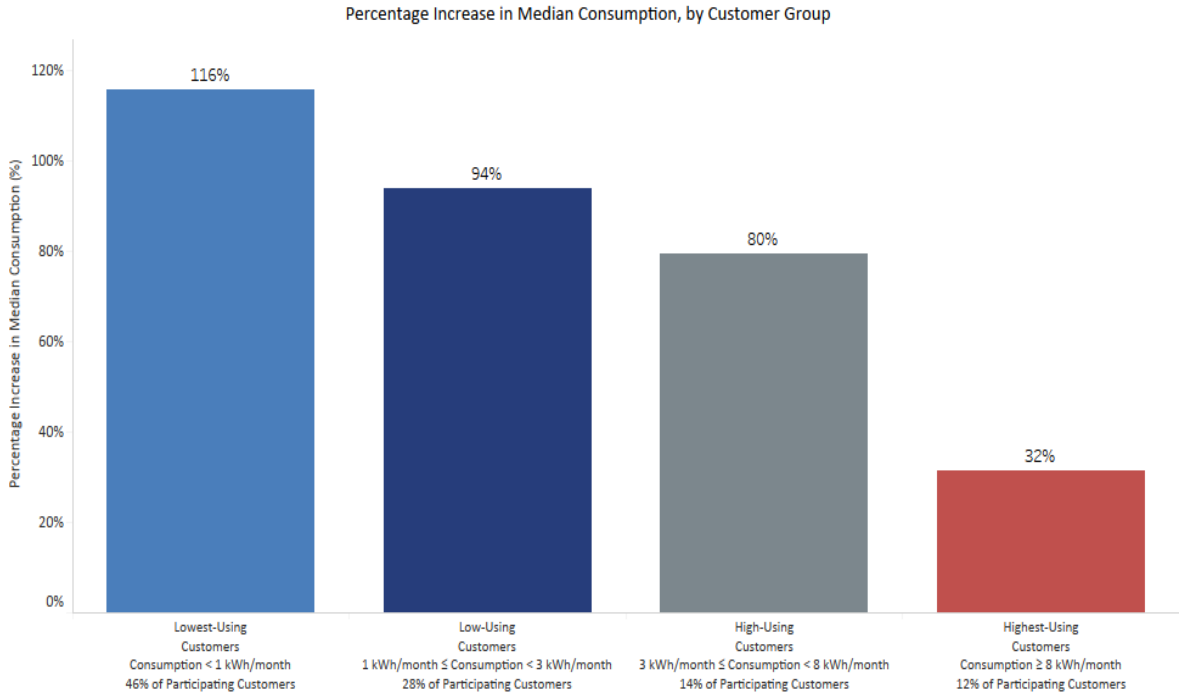
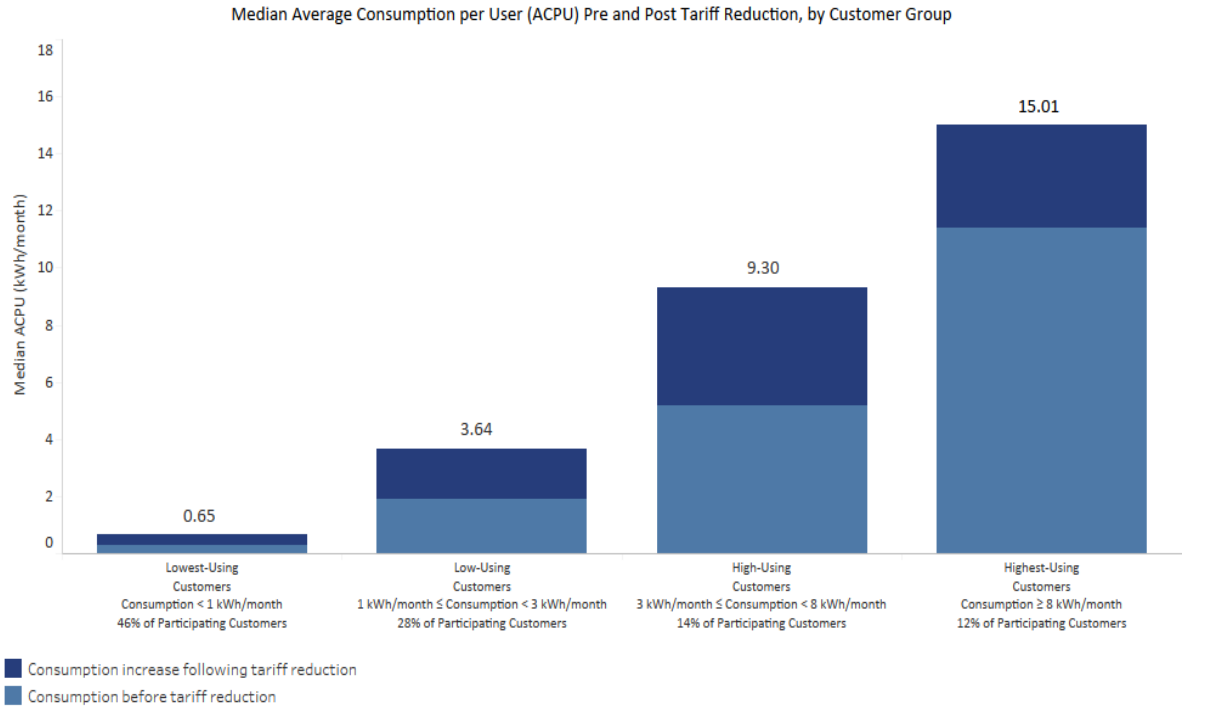
[1] This is equivalent to saying the price elasticity of demand for mini-grid power will be relatively elastic ($-\infty < E_d < -1$) by year five. The price elasticity of demand is defined as the percentage change in quantity demanded divided by the percentage change in price.

What it means: Customers immediately used 93% of the savings in price to spend on using more electricity, but after nine months have not yet increased their energy budgets. The Lab will continue to track how this develops over time.

Hypothesis 3: Historically low-user customers[2] will exhibit the largest percentage increase in consumption.



[2] Groups defined according to known levels of electricity usage. 1 kWh per month translates to roughly two lights for three hours per day, 3 kWh per month to two lights and a TV for three hours per day, and 8 kWh per month to two lights and a TV for three hours per day, plus a fridge for nine hours per day for ten days per month.

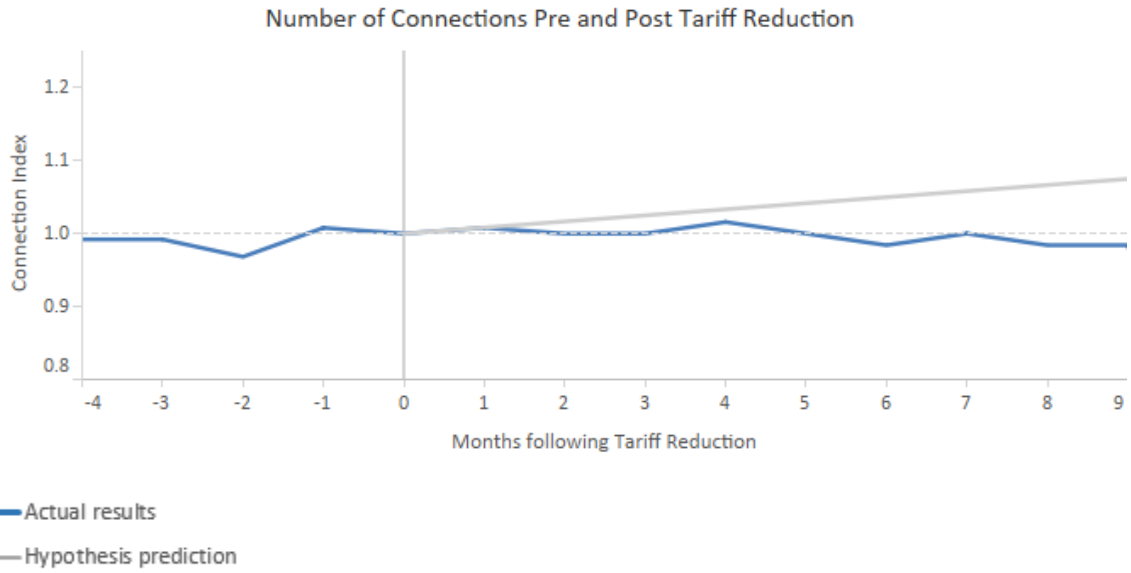


What we expected: The historically lowest-using customers are the most price-sensitive, and thus most responsive to a tariff reduction.

What we're seeing: The lowest-using customers prior to the subsidy showed the greatest percentage increase in consumption. They increased their median consumption by 116%, compared to 32% for the highest-using customers.

What it means: While higher-using customers have a greater capacity to grow their energy usage, in absolute numbers, the lowest-using customers have the greatest proportional capacity to expand their energy usage. Reducing the tariff on mini-grids can move a low-using customer, for instance, from using four lights for three hours per day to using nearly four lights plus a TV for three hours per day.

Hypothesis 4: The number of connections at treatment sites will be 10% greater after one year.



What we expected: Previously unconnected households and businesses connect to the mini-grid once electricity is made cheaper.

What we're seeing: The number of connections across both sites has remained essentially unchanged after nine months of the subsidy.

What it means: Connecting customers to a mini-grid typically requires a technical team at site. Therefore, there may be a delay in new customers requesting to be connected, and the developer sending a team out to site to do so. Developers are confirming how the number of new customer requests have changed since the tariff reduction, and we may see an increase in actual connections once teams go out to site.

VII. What we're going to do about it: the Lab will build the evidence base for scaling sustainable tariff reductions across Africa

The Innovation Lab improves the mini-grid business model by 1) proving innovations that improve the unit economics for mini-grids and then 2) scaling those innovations with developers and other implementation partners across the continent.

Before scaling, the Lab must continue building the evidence base to prove the impact of reducing the tariff on the mini-grid business model, <u>particularly where additional capex is required to meet increased demand</u>

	1 Prove	2 Scale
	…the optimal tariff reduction to unlock customer demand and increase revenues, and the tariff subsidy required to support that.	**…tariff reductions and tariff subsidies on all operating mini-grid sites across the continent.**
Innovation Lab 	***In the next three months…*** • Analyze the impact on developer profit should additional capex be required to meet increased demand • Test the prototype on a new site in Tanzania, increasing the number of connections under the prototype from 128 to 332 • Test the prototype on mini-grid sites in Nigeria and Zambia, with different types of customers, different tariff structures, and different grid sizes ***In the next six months…*** • Test a new iteration of the prototype, which may test subsidizing different types of consumption to varying degrees or implementing a subsidy across a cluster of mini-grid sites	***In the next year…*** • Encourage mini-grid developers to implement the tariff reduction on their own where it would be profitable • Prove the tariff reduction scheme to donors and investors, and connect funders with mini-grid developers in need of subsidies to implement the reduction • Develop materials with African Mini-Grid Development Association (AMDA) and Power for All to make the case for sustainable tariff reductions and mini-grid tariff subsidies

	1 Prove	2 Scale
Innovation Lab 	• Complete additional analysis to answer questions spurred by learnings, specifically regarding socio-economic impacts, the differences in impact among customer segments, customers' ability to move up the energy ladder, and the distinct roles hours and appliances play in the impact on consumption	
Mini-Grid Developers 	***In the next three months…*** • Identify sites capable of testing tariff reduction schemes and work with the Lab to implement the reduction on selected sites	***In the next year…*** • Implement a tariff reduction on operating sites
Funders 	***In the next three months…*** • Fund additional implementations of the Tariff prototype	***In the next year…*** • Fund subsidies on operating sites where the reduced tariff is lower than the mini-grid's levelized cost of energy (LCOE)
Government 	*N/A*	***In the next year…*** • Consider regulation providing subsidies on operating sites where the reduced tariff is lower than the mini-grid's levelized cost of energy (LCOE)