



CROSSBOUNDARY



ACCELERATING ACCESS TO ENERGY

Innovation Insight: Appliance Financing
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I. Introduction: the Mini-Grid Innovation Lab is publishing an *Innovation Insight* series to share actionable business intelligence on innovations to the mini-grid business model

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

CrossBoundary Advisory 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 provide advice and support on experiment design, survey 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 launched an *Innovation Insight* series to provide early, actionable business intelligence on initial results from its prototypes

The Lab's *Innovation Insight* series provides 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. Due to differing analytical methods and degrees of academic rigour, it is possible conclusions and interpretations between the two publications may somewhat vary.

II. Executive Summary: offering appliances on credit to rural mini-grid customers unlocks latent demand for electricity, and therefore increases revenues

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 people living off-grid in Africa.](#)

One of the fundamental challenges to the profitability of mini-grids is that rural customers' energy consumption is typically too low. If customers don't use sufficient electricity, there is not enough revenue for mini-grid developers to sustainably operate their grids. Customers' electricity consumption is limited by both how much they can afford and what they can do with electricity. For example, regardless of their energy budget, customers who own a single 5 W LED lightbulb can only use mini-grid electricity for lighting. This means they can consume no more than 1 kWh per month, even if they run the lightbulb 6 hours a night, every night. This is problematic for both customers and mini-grid developers. Customers are missing out on the full benefits of electricity, while their low consumption of electricity decreases the profitability of the mini-grid.

So why don't customers buy more appliances and use more power? One reason is that the upfront cost of appliances such as TVs and fridges is often too high for rural mini-grid customers. Offering appliances on credit, which has historically been an important part of efforts to drive demand in the US and Europe, may help overcome this barrier by breaking up the high upfront cost into more manageable monthly payments. To help developers determine whether appliance financing can profitably drive revenue and improve the mini-grid business model, the Innovation Lab is running an Appliance Financing prototype.

In 2018, the Lab supported seven mini-grid developers to sell 663 appliances on credit across 27 sites¹ in East Africa and Nigeria, the largest trial of appliance financing on mini-grids in Africa to date. Early results suggest rural mini-grid customers are ready to use more power than their current means to put electricity to use allow – appliance purchasers consumed nearly twice as much electricity for the first five months following appliance delivery, in both regions.

Average revenue per user (ARPU) across all customers (not just those who purchased appliances) also saw considerable increases sustained over time. In East Africa, revenues are 18% above baseline levels after 11 months; in Nigeria, that number is 25% after 5 months.

Of a range of household and productive use appliances, the most popular appliances were used for entertainment. Speakers² and TV sales made up 393 of the total 663 appliances sold.

¹ A site is defined as a single mini-grid.

² Speakers may refer to individual speakers or larger sound systems.

Speakers and TVs can improve site-wide consumption and ARPU due to their outsized popularity among customers. Their impact on an individual customer's revenues (around \$1.00-1.60/month) may be similar or smaller than that of higher power-consuming appliances such as fridges and freezers (around \$1.70/month). However, based on the number of sales per grid, and the increase in revenue per sale, entertainment appliances may drive the greatest increase in overall grid revenue.

We can make four principal observations at this stage of the prototype:

1. Offering appliances on credit has an immediate and strong effect on rural customers' consumption. *Rural customers are use- and credit-constrained.*
2. Mini-grid developers can raise revenues by implementing appliance financing schemes.
3. Procuring appliances, distributing appliances, and tracking loan repayments is operationally complex and requires significant developer resources.
4. Rural customers principally purchased household appliances. Productive use appliances such as carpentry tools were offered but very few customers purchased any.

It is important to emphasize that this initial data represents actionable intelligence rather than scientific evidence. These are preliminary results and may change with more data over time, or more data from additional sites and other markets.

By the end of the prototype we expect to have robust datasets over a full 12-month period to quantify observations (1) and (2) above with more confidence. In particular, we don't yet have a full picture of the costs associated with running these programs, nor rate of customer repayment on the appliance loans. At the end of the study, the Lab will release an updated *Innovation Insight* with more data and an analysis of program costs.

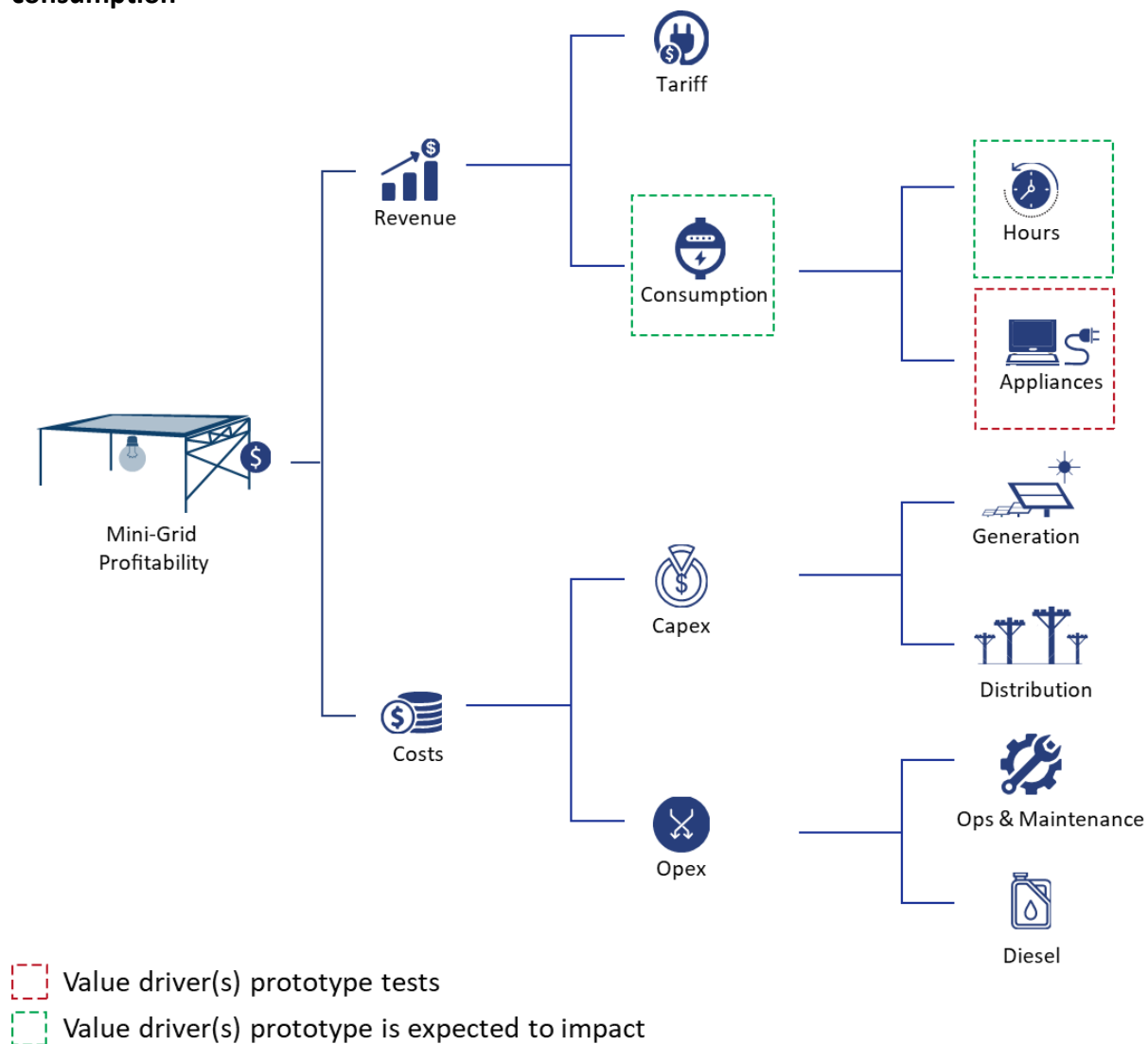
The Lab is also testing two iterations on this prototype to address observations (3) and (4). Launching in August 2019, the Lab will test the impact of:

- partnering with the payment platform Angaza to manage customers' loan repayments and reduce the administrative burden on developers, and
- offering only productive use appliances, but on longer payment terms of 18 months.

III. Why we're doing this: appliances drive customer consumption, and therefore mini-grid revenues

The Appliance Financing prototype tests the impact of offering **appliances**, on credit, on the mini-grid business model. The Lab expects offering appliances will impact electricity **consumption**, both because customers can use energy in new ways (**appliances**), and they have a reason to use energy for longer (**hours**).

The Appliance Financing prototype tests the impact of offering appliances on electricity consumption



IV. How we're doing it: funding developers to offer appliances to customers on credit

To test this prototype, the Lab provided funding for developers to run appliance financing programs at 24 mini-grid sites in East Africa and 3 sites in Nigeria. Together the sites represent 3,471 connections. Developers chose appliance offerings according to customer demand, the mini-grid's ability to sustain the load, and feasibility of procurement and distribution. Accordingly, appliance offerings varied by site.

The loan terms were set to reflect commercial standards, benchmarked against similar programs offered by solar home system providers. Financing was offered according to a 12-month loan term, with a 20% upfront deposit and a 2.55% monthly interest rate.³ All customers able to pay the upfront deposit were given the opportunity to purchase appliances through the program. Customer contracts included provisions that failing to meet loan repayments could result in their electricity being switched off, or appliance repossession.

In practice, for operational reasons, few developers implemented these measures. Shutting off a customer's electricity results in lost revenue and also risks long-term reputational damage for the mini-grid developer. Because a mini-grid serves an entire community, any damage to a customer relationship can impact the developer's entire customer base. Appliance repossession may not be worthwhile since the logistics involved can be very costly. We plan to explore improving enforcement mechanisms in future implementations of the prototype.

Following community engagement and customer registration, mini-grid developers distributed appliances at each site. No business training or education was provided to customers. Developers distributed 663 appliances in total. The Lab collected consumption, payment, and loan repayment data from each site on a monthly basis, and conducted two customer surveys to collect demographic, socioeconomic, and user experience data. In East Africa, the program has been running for eleven months; in Nigeria, the program has been running for five months.

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

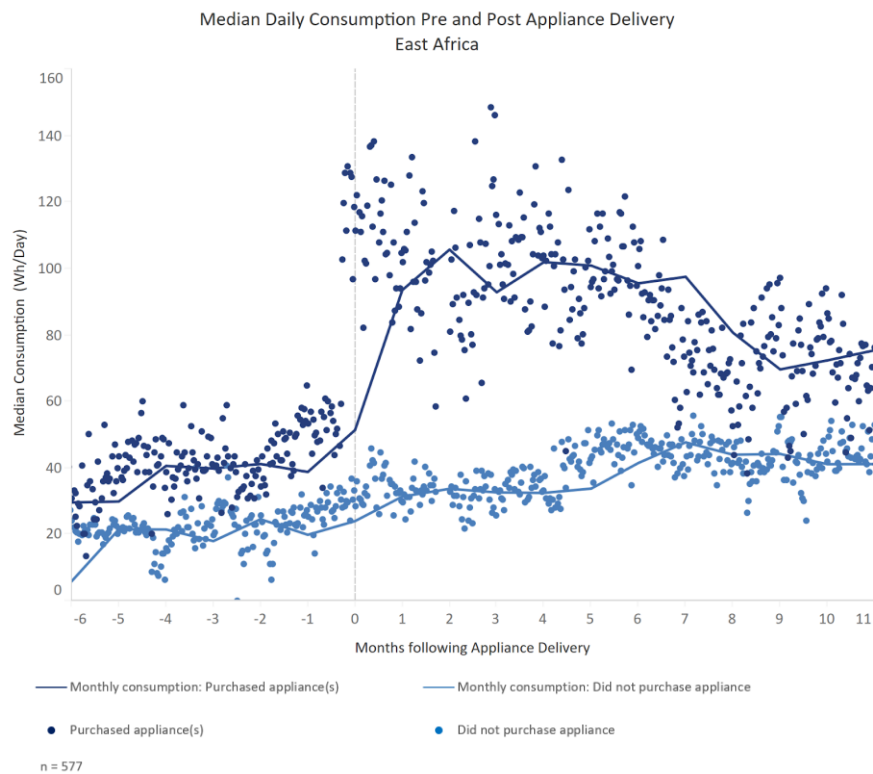
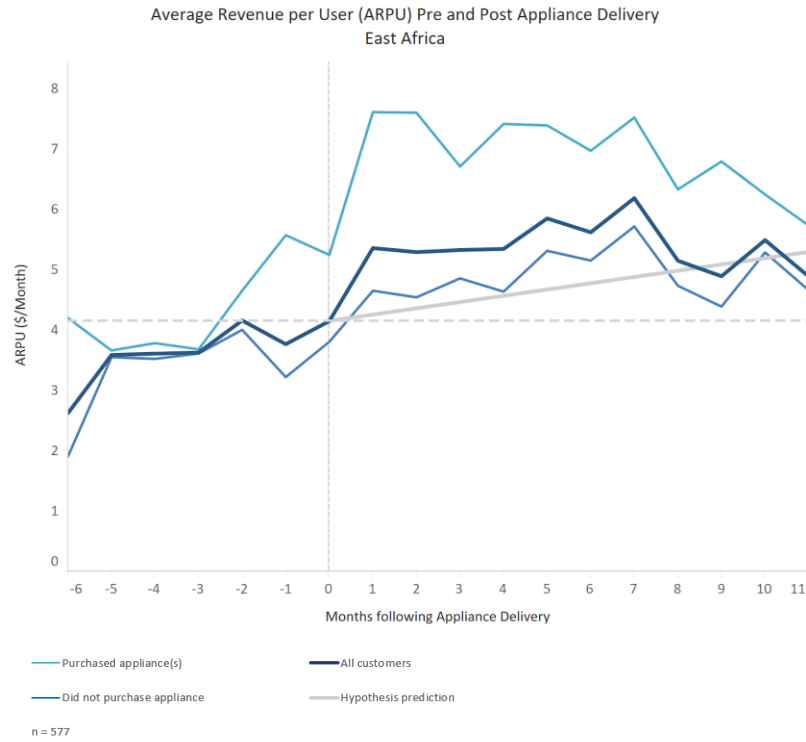
³Due to particular circumstances, some developers made minor adaptations to these terms.

V. What we're seeing: mini-grid customers who purchased appliances nearly doubled their consumption and total grid revenues increased by 18% after eleven months

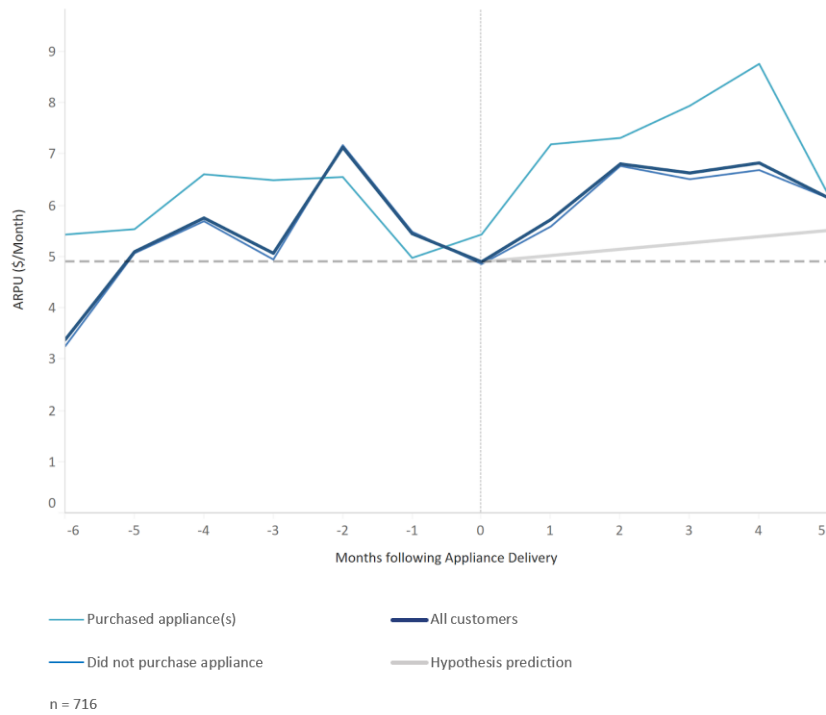
The Lab made four hypotheses on how we expected the prototype to impact the mini-grid business model. The following outlines, for each hypothesis: what we expected to see, what we're seeing, and what it means.⁴ The fifth hypothesis, which addresses the prototype's social impact, will be included in the final *Innovation Insight* published for this prototype. Customer surveys are conducted to collect customer-level data on spending, employment, and energy use, among other socio-economic metrics.

⁴ Axes marked by month reflect totals at the end of each month; axes marked by day reflect totals at the end of each day; axes marked by hour reflect totals at the end of each hour. We aggregate and report revenues using the mean, as average revenue per user (ARPU) is the metric most commonly used by mini-grid developers to evaluate revenues. We aggregate and report consumption using the median to provide a different perspective of the data. Sites experiencing sustained system outages or sizeable tariff changes were excluded from the analysis.

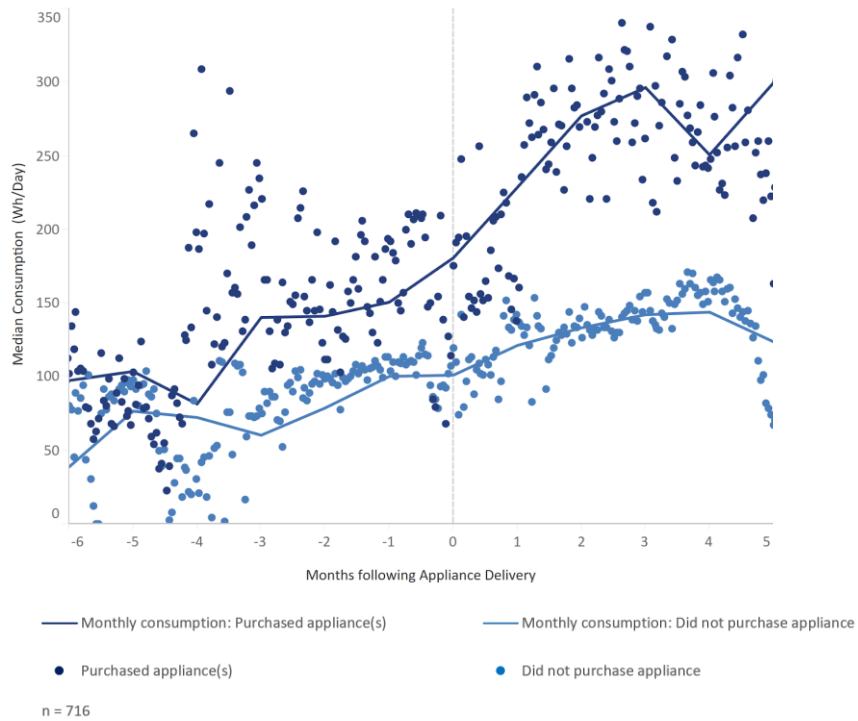
Hypothesis 1: Average revenue per user (ARPU) among all customers will be 30% higher after one year



Average Revenue per User (ARPU) Pre and Post Appliance Delivery
 Nigeria



Median Daily Consumption Pre and Post Appliance Delivery
 Nigeria



Offering appliances on credit increases overall grid revenues by 18% after 11 months

What we expected: Offering customers appliances will increase the number of customers using energy to power those appliances, and thus increase overall consumption. This will lead to a 30% increase in revenues for mini-grid developers.

What we're seeing: In East Africa and Nigeria, median monthly consumption among all customers increased by 52% and 22% respectively in the first five months following appliance delivery. Appliance purchasers in both geographies nearly doubled their consumption. In East Africa, this surge in consumption among appliance purchasers fell after nine months to 37% higher than baseline levels, perhaps due to customers moderating their appliance use in response to higher electricity bills or seasonal variation in activities and income.

Still, after eleven months, monthly ARPU across all customers in East Africa remains 18% (\$0.74) higher than baseline levels. Due to their higher than site-average ARPU at baseline, appliance purchasers' growth in ARPU is a smaller 9% (\$0.49).⁵

In Nigeria, consumption continued to rise, pushing ARPU across all customers to 25% (\$1.24) over baseline levels after five months. Consumption and revenue are not perfectly correlated, since tariffs are often lower for the highest-consuming customers. In Nigeria, where tariffs are considerably lower than in East Africa, consumption increases translate to smaller increases in ARPU.

Across all sites, customers who purchased appliances were on average higher consumers prior to the prototype launch. Appliance purchasers exhibited greater variation in consumption compared to non-purchasers, likely due to differences in the types of appliances used and a smaller population.

Interestingly, consumption among non-purchasers steadily rose following appliance delivery in both geographies. This could be in response to a spillover effect (e.g. neighbors borrowed appliances, or were inspired to purchase their own independently of the program), or simply due to

⁵ Appliance purchasers typically had higher than site-average ARPU at baseline, which explains the smaller percentage increase in ARPU among appliance purchasers.

natural growth at the site.⁶ The drop in ARPU among appliance purchasers in Nigeria after four months was caused by a single high-consuming customer reducing his consumption in response to bills greater than \$13/day, demonstrating the importance of such customers.

What it means: Rural mini-grid customers have greater demand for electricity than their current appliance ownership enables them to consume. There is latent demand for appliances, but high upfront costs and credit constraints prevent customers from purchasing appliances. Developers may be able to meet this demand, and grow revenues, by offering appliances on credit.

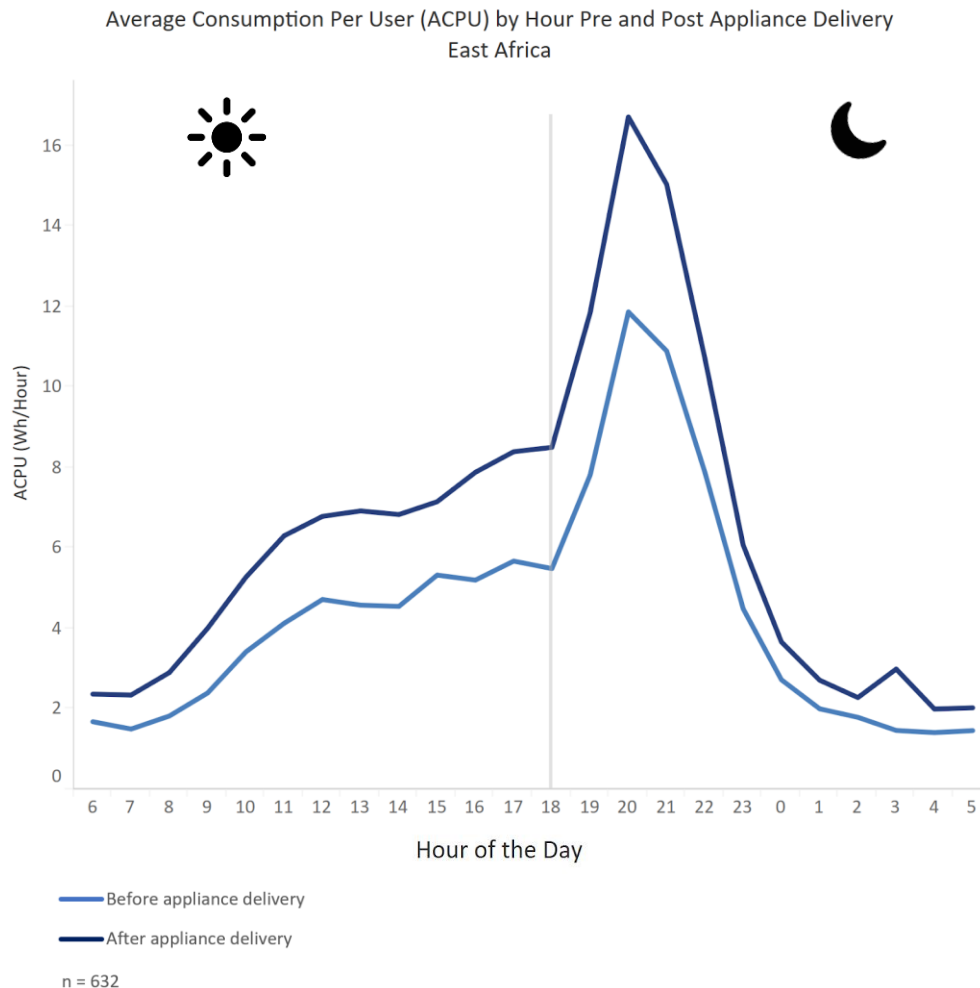
If East African developers can maintain the consumption and revenue levels seen in the first few months, they may be able to sustain increases in overall monthly ARPU of 40% (\$1.70). This might be possible by further reducing tariffs for high-consumers, or by offering business training and market linkages to enable customers to make full use of their appliances. Further analysis is required to determine if the increase in ARPU is sufficient to offset the costs of running the program.

Questions we'll answer in a future *Innovation Insight*:

1. How does consumption vary by appliance over time? Do freezers sustain consumption levels more than TVs?
2. How does ARPU vary by the kind of appliance a customer owns? Do customers with different appliances face a different effective tariff?
3. What causes fluctuations in consumption over time? What can developers do to sustain the high ARPU observed immediately following appliance delivery?

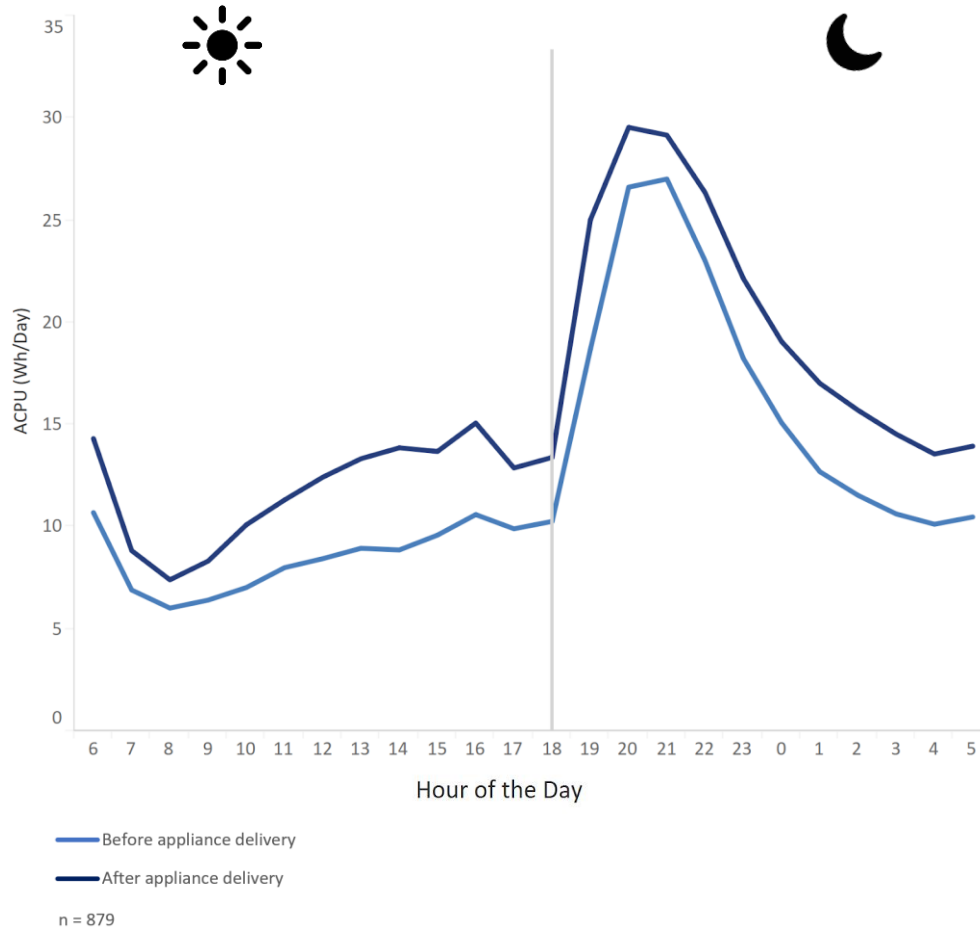
⁶ It is impossible to know precisely how consumption and revenue would have trended absent the program. However, anecdotal evidence from developers suggests that, without demand-stimulation programs, natural growth is small at sites that have been active for longer than 6 months.

Hypothesis 2: Consumption will shift to increased daytime usage, with a 10-percentage point increase in the proportion of electricity consumed during daylight hours



East Africa	Daytime consumption as percentage of total daily consumption	Nighttime consumption as percentage of total daily consumption
Before appliance delivery	46%	54%
After appliance delivery	47%	53%
Percentage point increase in proportion of daytime consumption	1	

Average Consumption Per User (ACPU) by Hour Pre and Post Appliance Delivery
 Nigeria



Nigeria	Daytime consumption as percentage of total daily consumption	Nighttime consumption as percentage of total daily consumption
Before appliance delivery	35%	65%
After appliance delivery	38%	62%
Percentage point increase in proportion of daytime consumption	3	

Offering household appliances on credit only marginally shifts consumption to daylight hours, when solar mini-grids supply least-cost energy

What we expected: Offering customers appliances will increase the number of customers using energy to power those appliances, and thus increase overall consumption. We expected this increase in consumption to be concentrated during daylight hours (6am-6pm) owing to customers buying high-consuming productive use appliances.

What we're seeing: In both geographies, the timing of customers' consumption shifted minimally. In Nigeria, the proportion of daytime consumption increased by 3 percentage points, with 38% of all consumption now occurring during daylight hours. In East Africa, where almost half of consumption already occurred during the day, the shift was only 1 percentage point.

This difference between the two regions may be explained in part by differences in the types of appliances purchased. TVs and speakers, for instance, were sold at higher rates in East Africa than in Nigeria and customers are more likely to use such appliances for entertainment in the evening. 62% of all appliances sold in East Africa were TVs or speakers, compared to 43% in Nigeria. In Nigeria, fridge and freezer purchasers increased their daily consumption five times more than in East Africa; these appliances are more likely to be used by shop owners during daylight hours.

What it means: Batteries are a major cost for mini-grid developers. If customers mostly use electricity during daylight hours, when the mini-grid generates energy, developers can minimize the number of batteries the grid requires to store energy and thereby minimize costs. Household appliances are largely used during the evening and thus do not aid developers in shifting consumption to match the grid's hours of generation. Offering appliances primarily used during the day, such as productive use appliances, may be an effective way of aligning consumption with generation and reducing costly battery storage. Further analysis is required to understand the potential magnitude of impact.

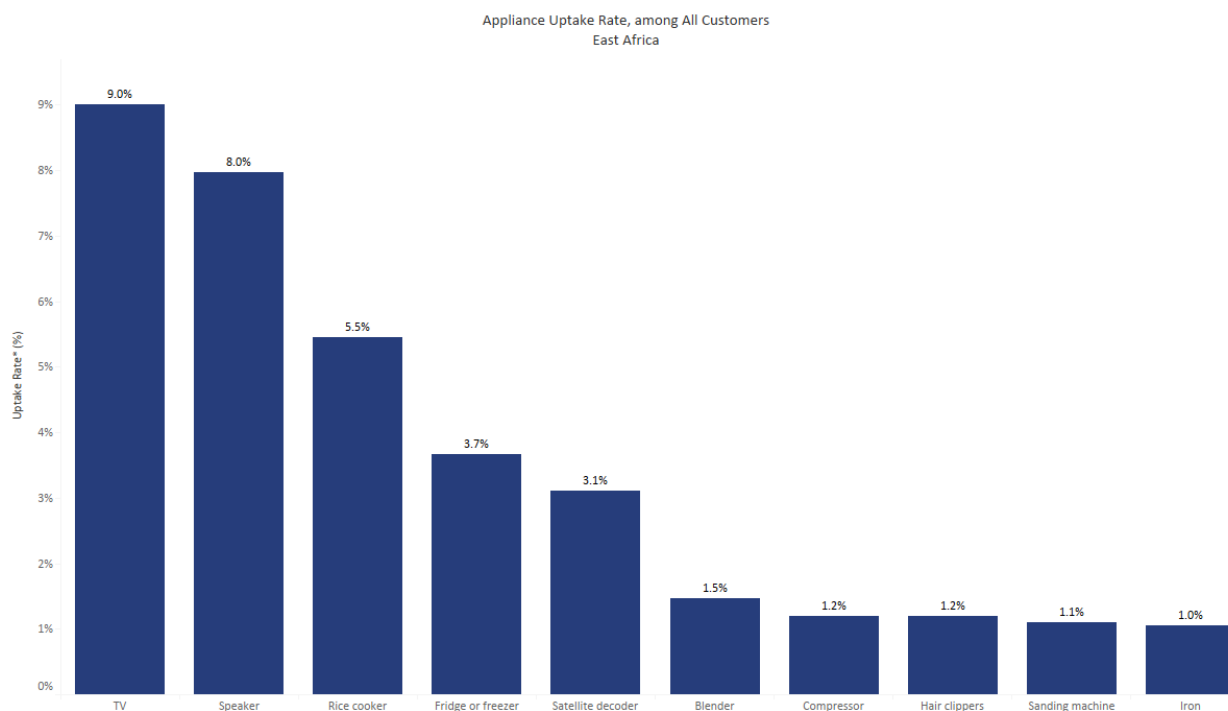
Questions we'll answer in a future *Innovation Insight*:

1. Which appliances most drive daytime consumption?
2. Does selling a greater proportion of productive use appliances further reduce the need for battery storage?

Hypothesis 3: Of all appliances, TVs will have the highest uptake rate among customers

Note: All graphs and tables show the top ten appliances for that metric. Developers chose which appliances to offer at each site, and how frequently to do so. As such, some offered appliances once at the program's outset, some offered appliances monthly while on site, and others accepted orders from customers at any time. The uptake rate is adjusted by site to account for the varying availability of appliances.

Beyond the appliances shown, the following were offered by at least one developer but not purchased by any customers: printers, water dispensers, irrigation pumps, desktop computers, blow dryers, photocopiers, home theatres, and photo printers.



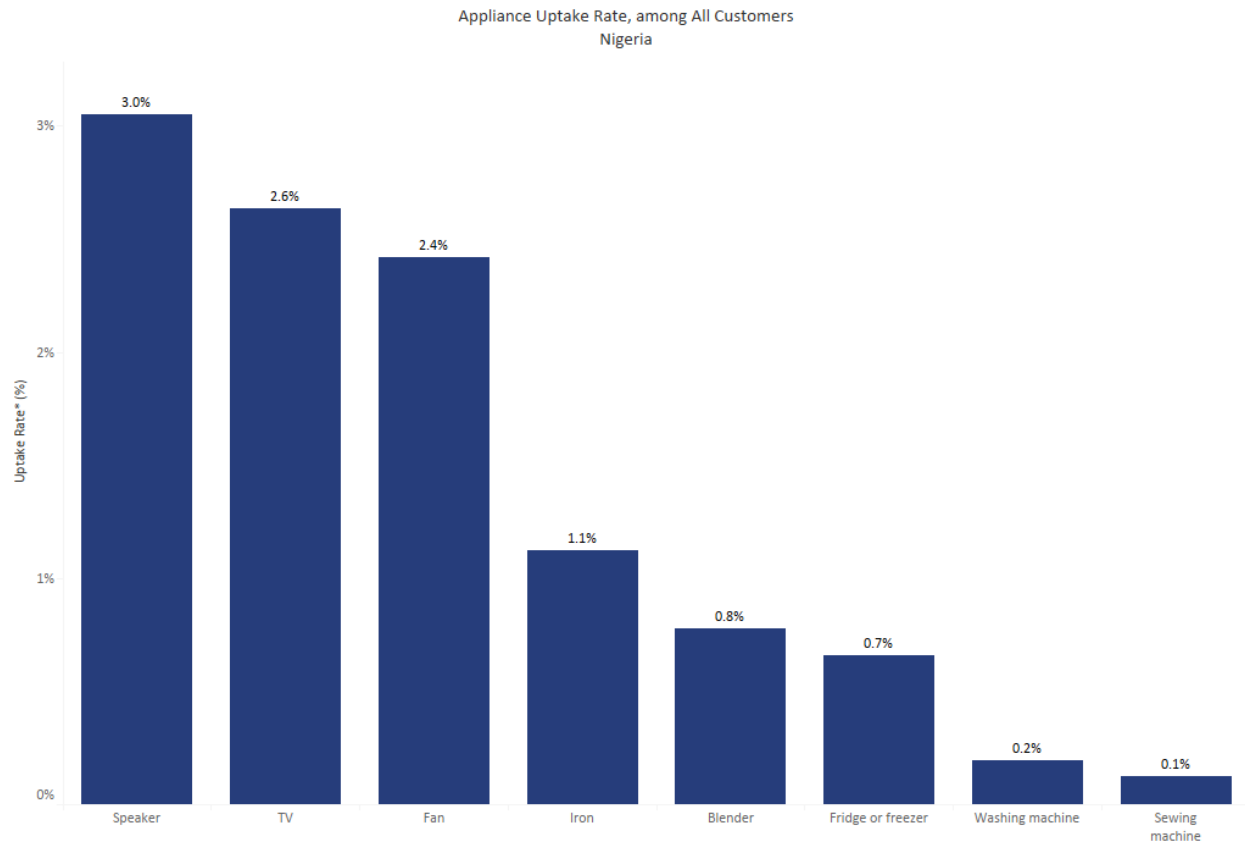
**Calculated as the number of customers who purchased a certain appliance over the number of customers given the opportunity to purchase that appliance*

Note: As not all appliances were offered at every site, uptake rate is adjusted by site to account for the number of potential purchasers.

Appliance Uptake Count, among All Customers
East Africa

	TV	Speaker	Fridge or freezer	Satellite decoder	Blender	Hair clippers	Iron	Welding machine	Sanding machine	Rice cooker	Other Appliances*
Number purchased	194	156	76	61	26	19	10	4	4	3	11
Number of customers offered	2155	1959	2072	1959	1778	1599	957	592	363	55	N/A

**Includes egg incubators, grinders, fans, air compressors, drills, and laptops*



**Calculated as the number of customers who purchased a certain appliance over the number of customers given the opportunity to purchase that appliance*

Note: As not all appliances were offered at every site, uptake rate is adjusted by site to account for the number of potential purchasers.

Appliance Uptake Count, among All Customers
Nigeria

	TV	Fan	Speaker	DVD player	Iron	Fridge or freezer	Blender	Washing machine	Sewing machine
Number purchased	24	22	19	13	9	6	4	1	1
Number of customers offered	910	910	623	910	803	623	516	516	803

Entertainment products, such as TVs and speakers, were the most popular appliances.

What we expected: TVs will have the highest uptake rate among rural mini-grid customers, meaning a greater proportion of people will choose to purchase a TV than any other appliance, when given the opportunity.

What we're seeing: TVs were the most commonly purchased appliance in both East Africa (194) and Nigeria (24) in terms of volume sold. They also exhibited the highest uptake rate of any appliance in East Africa, where nearly one in ten customers given the opportunity to purchase a TV did so. In both geographies, speakers proved similarly popular in terms of uptake rate, though slightly fewer were sold overall.

What it means: Procuring and distributing appliances can be costly, particularly to remote rural customers. Offering entertainment products such as TVs, speakers, DVD players, and satellite decoders⁷ may improve customer uptake and minimize program costs by streamlining offerings. More expensive appliances, such as fridges and freezers, are likely to be purchased by fewer customers and thus may be more costly on a per appliance basis for developers to procure and distribute.

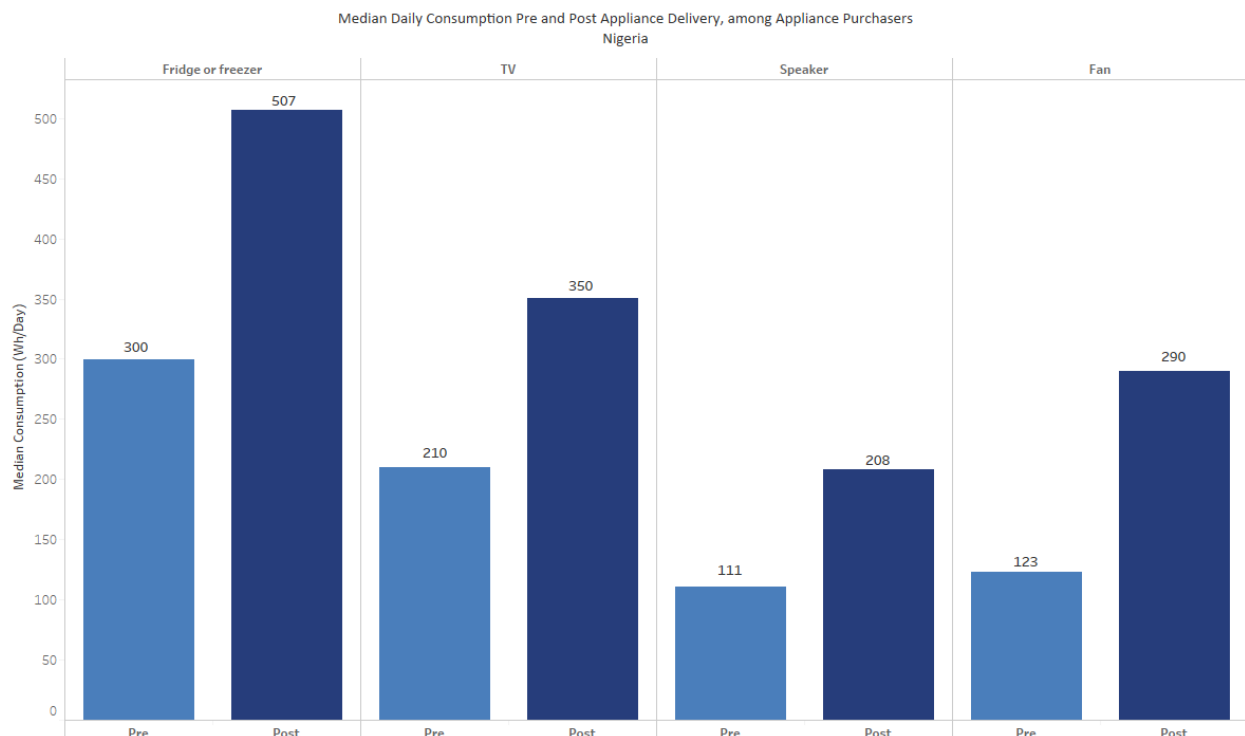
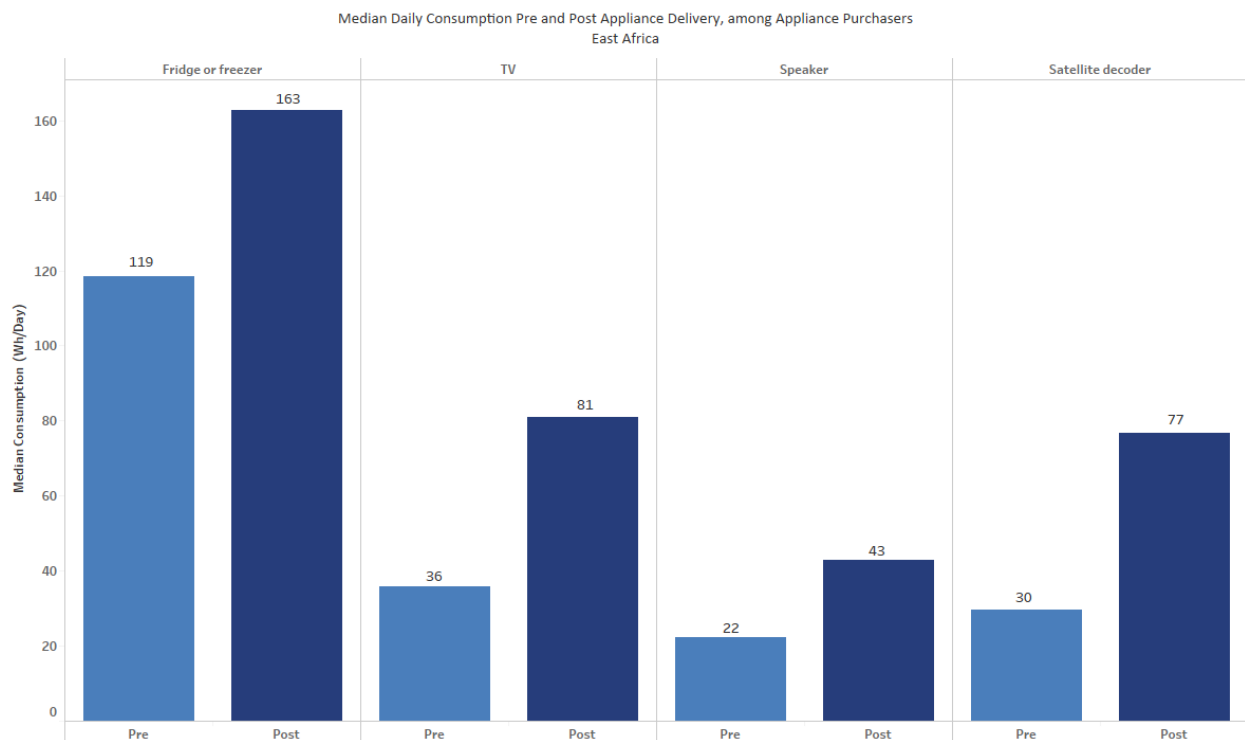
Questions we'll answer in a future *Innovation Insight*:

1. How do procurement and distribution costs vary by appliance?
2. How do these trends change, if at all, as more low-consuming customers choose to purchase appliances?
3. How can developers encourage customers to purchase more productive use appliances?

⁷ Satellite decoders enable customers to access satellite TV.

Hypothesis 4: Fridge and freezer purchasers will exhibit the largest absolute increase in consumption

Note: The appliances shown in the following bar charts were selected according to market interest. The numbers shown represent median daily consumption.



Fridge and freezer purchasers do not definitively increase their consumption the most in absolute terms, contrary to expectations

What we expected: Fridges and freezers use more energy than other appliances offered because they must have a continual supply of power to run and consume much more power per hour. Moreover, customers who can afford to purchase fridges and freezers are likely to have greater disposable incomes and are thus able to increase their consumption the most.

What we're seeing: In East Africa, customers purchasing fridges or freezers did not increase their daily consumption any more than customers purchasing TVs or satellite decoders.⁸ In fact, customers purchasing TVs and decoders more than doubled their daily consumption, increasing it by approximately 45 Wh per day (1.4 kWh per month). For a 30 W TV, this implies 1.5 hours of TV use per day.

A customer using a 100 W freezer would increase his/her consumption by 30 kWh per month⁹. The unexpectedly low increase in consumption we observe among fridge and freezer purchasers (1.32 kWh per month in East Africa; 6.2 kWh per month in Nigeria) is likely due to customers regularly turning off their fridge or freezer. This may be in response to high bills and/or the mistaken belief that a continual supply of power is not necessary to run the appliance.

In Nigeria, although the increase was smaller than expected, fridge and freezer purchasers did increase their consumption the most. Like satellite decoder and TV purchasers in East Africa, fan purchasers in Nigeria more than doubled their daily consumption. Overall consumption levels for all customers were considerably higher in Nigeria than in East Africa, likely driven by lower tariffs that allow Nigerian customers to more readily change their energy consumption patterns. It is important to note that only six customers purchased fridges or freezers in Nigeria, and the program has only been running for five months relative to East Africa's eleven months. More data is required to understand whether that accounts for the differences seen between geographies.

What it means: Providing customers with fridges and freezers may not drive a greater increase in individual consumption than providing smaller entertainment

⁸ The increases in median daily consumption among TV, satellite decoder, and fridge or freezer purchasers in East Africa were 45 Wh, 47 Wh, and 44 Wh, respectively. We consider these numbers indistinguishable.

⁹ Refrigerator compressors typically only draw power for 10 hours a day when plugged in continuously as they only run when they need to reduce the temperature below the set threshold.

appliances, particularly if customers are not accustomed to behavior change. Furthermore, given TVs and speakers are more likely to be sold in high volume, they may have a greater impact on overall grid consumption. Promoting smaller entertainment appliances may be an effective way of increasing energy usage among low-consuming customers and driving site-wide revenue. Still, there must be a balance between providing household appliances that enable customers to *use* more electricity, and productive use appliances that enable customers to *afford* more electricity.

Questions we'll answer in a future *Innovation Insight*:

1. Which appliances lead to sustained increases in customer consumption and why? Does customer income play an important role?
2. What explains the difference in the impact of fridges and freezers between East Africa and Nigeria? Are customers running their fridges and freezers continually?
3. Why are consumption increases so much greater in Nigeria than in East Africa?
4. Are there other characteristics, beyond impact on revenues, that make some appliances a better offering than others?
5. Is it more profitable to distribute high-volume, low-consuming appliances or low-volume, high-consuming appliances?
6. What additional services, such as business training and market linkages, enable customers to generate the most income from productive use appliances?

Estimating the impact of individual appliances on overall site revenue

The following table estimates the impact on total revenue of offering different appliances at a site of 100 customers. We take the average increase in ARPU among owners of each appliance type and use uptake rates to scale it by the number of expected purchasers at a site of 100 customers.

Note: for those customers who purchased multiple appliances, we cannot disaggregate the change in ARPU driven by the use of each individual appliance.

Region	Appliance	Expected increase in monthly ARPU per appliance owner	Expected purchasers at a site of 100 customers	Expected increase in overall annual revenue at site
East Africa	TV	\$1.64	9	\$177.10
	Fridge or freezer	\$1.68	4	\$74.61
	Speaker	\$1.46	9	\$155.85
	Satellite decoder	\$2.03	3	\$75.56
Nigeria*	Speaker	\$0.47	3	\$16.95
	Fan	\$1.14	2	\$32.93
	TV	\$0.99	3	\$30.88

**Fridges and freezers are excluded from the Nigeria ARPU analysis because too few customers purchased either appliance to draw robust insights.*

At a site of 100 customers, developers may drive the greatest increase in ARPU by offering popular entertainment products such as speakers and TVs, rather than high-consuming products such as fridges and freezers. Although the per-unit impact on ARPU may be similar or smaller, TVs' and speakers' high uptake rates generate a large cumulative effect. Further analysis is required to determine the expected impact on profitability by appliance.

VI. What we're going to do about it: the Lab will refine the program design to determine if there is a sufficient evidence base for scaling appliance financing programs 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 offering appliances on the mini-grid business model

