



# POWERING PRODUCTIVITY

*Early Insights into Mini Grid Operations in Rural Kenya*

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'Bright Light Syndrome' is a term often used to explain the migration of young people towards urban areas; opportunities for gainful employment are usually cited as the most important reason for leaving rural villages. With Vulcan's mini grids, we've turned the bright lights on in 10 villages in rural Kenya. The arrival of power allows for entrepreneurship. The majority of new businesses in the villages we've electrified have been started by the younger and more tech savvy people. We've learned that, as a result, fewer young people are leaving the village because of these newly available job opportunities.

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## Executive Summary

More than 2 billion people around the world lack reliable access to electricity. The least electrified region is sub-Saharan Africa, where some 620 million people – mostly in rural areas – lack power. Many governments and utilities have expressed intentions to expand national grid capacity, but with high up-front costs and low consumption by individual users, publicly funded rural electrification has been extremely slow.

The off-grid energy industry is tapping into the opportunity presented by a vast market of unconnected people, resulting

in the development of innovative business models and technologies. Yet, the electricity usage behaviors of the people that these new businesses aim to serve is not well understood. Understanding this market, and serving it well, requires real world-experience and operational data.

Beginning in 2014, Vulcan Inc. and steama.co developed and have been operating ten solar powered off-grid mini grids of 1.5 – 6 (kw) in distinctly different villages across Kenya. Our goal is to demonstrate the potential of the mini grid sector to be commercially successful

and to generate valuable experience and insights to share with other off-grid businesses and investors.

This white paper is the first of several data-driven research pieces that will be produced by Vulcan and steama.co. It focuses on consumption and revenue growth and on building a knowledge base about rural consumers' ability and willingness to pay.

## Key Lessons

- Rural customers are willing and able to pay for electricity at tariffs as high as USD \$4.00 / kilowatt hour (kWh) (unsubsidized). Payment systems need to align with how and when these customers generate income. Commercial customers (i.e. businesses) in high-traffic areas are the most profitable.
- Average revenue per user (ARPU) range from USD \$0.38 to USD \$15.38 per month across the ten sites. The average ARPU for the portfolio is USD \$5.34.
- Most consumers initially use <250 watt-hours / day. When surveyed, customers tend to overestimate how much electricity they plan to use by an average of 15 percent.
- The top 10 percent of consumers have a five-time higher ARPU than the ARPU of the remaining 90 percent of customers and generate 40 percent of total revenue. Measurable indicators of these high-use consumers are:
  - Higher digital literacy - can comfortably SMS on their phones
  - Already own small-scale solar products – they are in a position to move up the “energy ladder”
- Electricity usage fluctuates widely based on factors including holidays and seasons; ARPU across Vulcan's sites is typically highest in December and lowest in February.
- Remote monitoring technology on both the power generation and power use helps resolve many issues cost-effectively, reducing uncertainty and maintenance costs.
- Most energy consumption occurs between 6pm - 10pm. This has a significant impact on the capacity need, and therefore the cost, of battery storage, which is the single largest category of capital expenditure.
- Demand for mini grid electricity is strong and growing. Surveyed consumers cited economic growth, increased security and health benefits. Mini grid consumers shifted almost entirely away from fossil fuels, resulting in a reduction of greenhouse gas emissions, local air pollution and safety risks.

## What's Next?

Vulcan and steama.co will continue to conduct quantitative studies to further analyze demand growth, profit forecasts, and mid-term economic and social impact. The results of our studies will be available in 2017.

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# 1. Opportunity

## 1.1 Introduction to Rural Electrification

More than 2 billion people around the world do not have reliable access to electricity. Sub-Saharan Africa has more people living without access to electricity – some 620 million – than any other region in the world, with approximately 80 percent of these living in rural areas. Providing clean, sustainable electricity to these energy-impooverished people could:

- Create 1.5 trillion additional productive hours
- Save USD \$38 billion in carbon-based energy expenditures
- Increase household per capita income by 38 percent per year

Sub-Saharan African governments and

utilities aim to expand grid capacity and rural connections, but with high up-front costs and low consumption by individual users, publicly funded rural electrification has lagged well behind demand. As populations grow, the demand gap continues to expand. This opens the door to innovative business models for private rural electrification using clean, sustainable off-grid technologies.

“ Africa is growing, and to grow Africa needs energy. What’s exciting is that we have the chance to leapfrog dirty fossil fuel based energy and to power African economies using solar.”

Harrison Leaf  
CEO and Founder of Steama.co

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## 1.2 Vulcan’s Goals

When Vulcan Impact Investing began exploring its investment in mini grids, very little operational or financial data was available. In order to catalyze momentum for the operation of mini grids, Vulcan invested in a set of 10 solar-powered mini grids in rural Kenya. We manage the mini grids in partnership with steama.co, a remote monitoring technology company.

Vulcan had three goals for owning and operating the mini grids:

1. Demonstrate a commercially viable business model for rural mini grids
2. Generate positive social, environmental and economic impact, particularly by providing clean, sustainable power to fuel economic growth
3. Catalyze further investment in mini grids by sharing what we learn with others

This white paper is the first of several data-driven research pieces that Vulcan and steama.co will produce and share. It focuses on consumption and revenue growth and on building a knowledge base about rural consumers’ ability and willingness to pay.

“ We set out to prove you could sustainably provide renewable power to rural, low-income Africans. Once this is proven, the door will be opened for the hundreds of millions without power.”

Lauren Kickham  
Vulcan Impact Investing Lead

## 2. Program Design

### 2.1 Site Selection

Vulcan, steama.co and the construction contractor, PowerGen Renewable Energy, engaged in a detailed site selection process assessing five categories:

- Energy demand
- Site economics
- Project logistics
- Potential for community development
- Overall potential impact

#### TWO SCORES WERE CALCULATED FOR EACH SITE:

- Commercial score, heavily weighting economic activity and electricity demand categories
- Impact score, heavily weighting community development and local impact categories

After assessing more than 200 potential sites, Vulcan chose five sites with the greatest potential for commercial success (Entesopia, Barsaloi, Merile, Opiroi, Olturoto) and five sites with the greatest

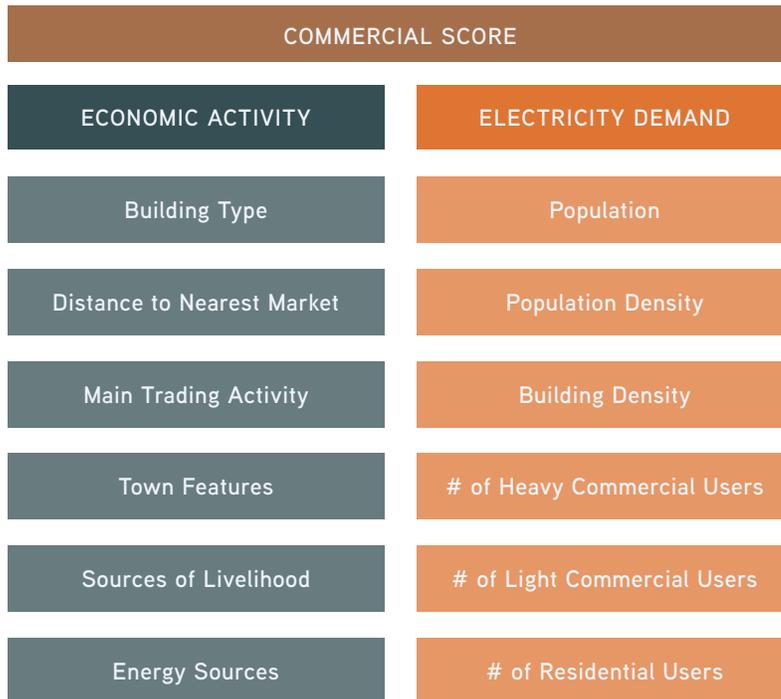
potential to transform village economies (Marti, Namba Koloo, Singiraine, Enkoireroi, and Olenarau). We chose a diverse set of sites so that our data would be richer and allow us to observe differences between our sites and our customers.

Economic activity and electricity demand categories assessed to determine the commercial score appear in FIGURE 1. The impact score incorporated 1) community development category (e.g. number of community activities and presence/absence of a local chief) and 2) local impact category (e.g. social, environmental and economic impact). Vulcan commissioned an in-depth impact assessment of the 10 selected sites to establish the baselines for the communities and for follow-up studies. These assessments included:

- Business census questionnaire
- Business diversity questionnaire
- Household survey
- Focus group discussions

“Now I can handle any kind of repair work my customers require.

*John Pambio  
Entesopia resident*



**FIGURE 1**

For each potential site two scores were given based on a variety of factors. The commercial score heavily weighted economic activity and electricity demand categories. The impact score heavily weighted community development and impact categories.

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## 2.2 Grid Design

Vulcan collaborated with steama.co and PowerGen to utilize site selection and baseline survey information to design the mini grid systems. Energy is generated from arrays of 235 Watt (W) direct current (DC) solar photovoltaic (PV) panels, and distributed to customers at 50 Hertz, 230 Volt alternating current (AC) through an inverter. The grids' capacity ranges from 1.5 to 6.0 (kW) AC. The number of customers per site ranges from 12 (at the 1.5 kW site) to 61 (at a 6 kW site).

Some of the systems' distinguishing features are steama.co's cloud-enabled smart meter and software, which help remotely monitor and manages off-grid electricity. The system allows for live, web-based monitoring of each customer's energy consumption, automated payment collection through a mobile money system, and automated customer

support via short message service (SMS). Customers get access to account information, low balance warnings, and payment confirmation through steama.co's automated SMS menu.

Any issues with grid operations can be seen via steama.co's remote monitoring platform. As the first line of response, a local site agent is deployed to check the issue. If the issue cannot be resolved by the site agent, a steama.co field employee visits the site to make necessary repairs. Trained site agents also engage the communities on a continuous basis, providing prompt customer service.

“I had a diesel generator before, but this mini grid electricity is much cheaper and easier”

- User Nancy Kaisa

*Sinigraine mini grid customers*



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## 3. Recruiting Your Customers

Drawing from two years of operating data from the mini grids, Vulcan and steama.co gained insight into best operating practices. This section shares insights and lessons regarding our customers and their consumption patterns.

We discuss:

- Commercial opportunity
- Digital system engagement
- Energy ladder
- Local cultural factors

Data provided is from the first full month of operation of each of the mini grids through May 2016. Data from entire months in which technical issues severely affected operations are excluded from trend analyses.

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### 3.1 Commercial Opportunity

The more profitable grids are those that have a high number of commercial customers, who tend to spend more on electricity. Villages with larger populations (e.g. greater than 1,500) or with significant through-traffic provide a greater opportunity for commercial customers. A diversity of commercial customers in the village is also important to the overall success of the mini grid. This is because while any given villager may only visit and use the electricity of one hair salon, that same person may give his/her business to a general store, phone charging station, common television venue, pharmacy and miller, if they exist. As a result, diverse commercial customers often consume electricity due to the business of the same customer.

Seasonality also factors into the need for business diversity. Droughts have a significant impact on rural electricity consumption, so in agricultural

communities it's important to understand how many local businesses are directly related to such production (e.g. mills) and how many are not directly related (e.g. phone charging stations). This applies more broadly to any economic activity in which seasonality plays a role, such as herding or fishing, and which is the major source of income for a community. The most successful sites are those where some businesses are either not directly tied to seasonality or are profitable in different seasons.

#### KEY INSIGHTS

High numbers of commercial customers (i.e. businesses), who spend more on electricity, improve profitability

Large populations and/or a significant number of people who pass through the town facilitate commercial customers and, subsequently the mini tgrids, being successful

Diversity of commercial customers in a village increases overall mini grid profitability

Seasonality severely impacts commercial customers' need for and spending on electricity

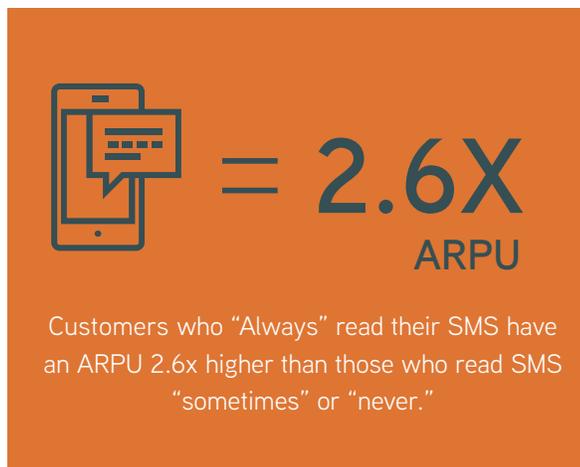
### 3.2 Digital System Engagement

Data suggests that individual customer consumption is linked to his or her ability to read and respond to automated SMSes in Swahili. Messages sent from the steama.co metering platform allow customers to check their account balance and receive payment reminders and notifications. People who do not often use mobile phones or M-PESA, or cannot read, or can read only a tribal language rather than Swahili, tend to have greater difficulty using the system.

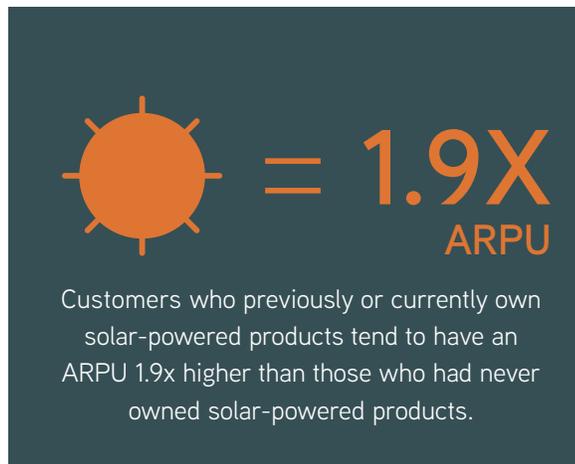
A user survey indicates that ARPU was 2.6x higher for customers who “Always” read their SMS compared to people who did so “Sometimes” or “Never”. This may also indicate a familiarity with mobile technology, which lowers the barrier to making mobile payments. Literacy and experience with SMSes appear to be indicators of a higher ARPU and should be tested during site selection and system design.

#### KEY INSIGHTS

Digital literacy may indicate a customer with a higher potential Average Revenue Per User (ARPU). This literacy can be tested during the site selection process by analyzing SMS engagement among potential customers



**FIGURE 2 (LEFT)**  
*Impact of digital literacy on ARPU*



**FIGURE 3 (RIGHT)**  
*Impact of solar product ownership on ARPU*

### 3.3 Energy Ladder

ARPU was 1.9x higher among survey respondents who either currently or have previously owned solar-powered products, as illustrated in FIGURE 3. This may seem counterintuitive, since owners of solar-powered products already draw a portion of their energy consumption already met. However, there are a number of factors which might be contributing to this. Users with such products:

- Tend to be more familiar and therefore comfortable with mobile money/PAYG systems, since many solar products are sold or leased using PAYG systems
- Understand the value of energy, having invested in energy products before, and therefore may better understand how to monetize their mini grid connection to grow their business
- Could afford energy investments in the past; they may therefore be more economically stable than the average rural resident

#### KEY INSIGHTS

Customers who previously or currently own solar-powered products tend to have higher ARPUs

Customers often work their way up an energy ladder – starting with pico systems before advancing to mini grids or other larger systems

Some customers stack energy equipment

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### 3.4 Local Cultural Factors

Due to the predominance of informal economies and complex cultural practices in rural communities, standard survey questions do not always provide the best insight into customers' socio-economic status and cultural practices. We learned that it is helpful to identify other indicators which can serve as proxies for common attributes and indicators of a potentially high-revenue customer. Two of these proxies were ownership of solar lanterns and frequency of SMSing, as previously described.

Highly localized cultural factors may significantly affect customer spending. In Vulcan's mini grid portfolio, the northern sites underperform compared to the sites located closer to Nairobi. We believe that cultural differences impact consumption. Social status in northern tribes is linked to cattle ownership, and many of these customers prefer to spend

their income on purchasing more cattle. For customers in sites closer to Nairobi, ownership of high-end appliances is a greater status symbol, and there is a corresponding inclination to spend more on larger appliances and electricity. Larger appliances are important, as the typical electricity draw of a television or refrigerator is to 5-10x the typical draw of a lightbulb or phone charger.

These examples demonstrate how cultural nuances can affect a mini grid's financial performance and the importance of understanding these nuances when evaluating potential mini grid sites.

#### KEY INSIGHTS

Survey questions about income may not adequately capture customer profiles, so proxies, (e.g. use of SMS, which indicates digital literacy) may provide more accurate customer information

Cultural factors may significantly affect grid profitability, so be sure to engage a site survey team that is familiar with local village politics and culture.

*Mini grid installation in progress*



## 4. Generating Revenue

### 4.1 Average Revenue Per User

ARPU varied widely by site and month. Average ARPU across the site portfolio was USD \$5.34/MONTH, with a maximum ARPU of USD \$15.38/MONTH and a minimum ARPU of USD \$0.38/MONTH. The site-specific ARPU ranges are shown in FIGURE 4, (NEXT PAGE).

December generated the peak ARPU at most sites, while February generated the lowest. There was a 21 percent average variation in total revenues from month to month (see FIGURE 5, NEXT PAGE). The overall trend of revenue was positive, although further data is required to control for true seasonality.

The seasonal pattern is likely due to a combination of cultural and environmental factors. During the December holidays, customers are inclined to increase electricity consumption to accommodate family visits and activities. The slump in February is most likely due to a post-holiday slowdown and the first dry season which reduces agricultural activity and corresponding electricity consumption. Other factors, such as payment of school fees, may also play a seasonal role.

To understand what makes sites commercially successful, one must look beyond site-level data. It is important to review data at the individual customer level and to understand the aggregated spending patterns. There is significant

variation of ARPU values across the customer portfolio. The top 10 percent of customers generate an annual ARPU almost 5x that of the portfolio annual ARPU, as noted in FIGURE 6. The average daily energy consumption is 100 watt-hour/day, which is roughly equivalent to three 10W compact fluorescent lights illuminated for 3 hours per day.

In particular, the top 10 percent of users generate roughly 40 percent of the revenue. This top 10 percent consumes an even higher percentage – roughly 50 percent – of total consumed electricity, but receive better, economy-of-scale rates. These high-users are the businesses which use high-energy appliances to generate income, and can therefore compensate for the mini grid customers who consume less.

Despite the importance of commercial customers, residential customers should not be discounted. They provide a stabilizing factor by volume, mitigating the attrition of major customers. With just a few high-income customers on any given mini grid, the financial impact of one customer leaving can be significant. As long as customers meet a certain threshold of ARPU (determined by capital expenditures and desired payback period), customer volume is an important component of a mini grid's commercial success.

#### KEY INSIGHTS

There is significant seasonal variation in monthly revenue totals, and this should be factored into financial models

ARPU ranges significantly throughout the year; it is generally highest in December and lowest in February. Accurate consumption growth numbers require multiple years of data, and are not generally applicable on a monthly basis

A limited percentage of customers generate high ARPUs, while the bulk of customers fall within a lower ARPU range, with an average of USD \$5.34/MONTH

The bulk of customers fall within a lower energy consumption level (< 250 WH/day)

A customer mix that includes a high number of lower-ARPU customers helps hedge against the potential loss of larger, individual customers

#### FIGURE 6 (BELOW)

*Impact of digital literacy on ARPU*

The top 10 percent of customers have an ARPU that is 5x greater than the grid average, generate roughly 40 percent of the revenue, and consume roughly 50 percent of the total consumed electricity.

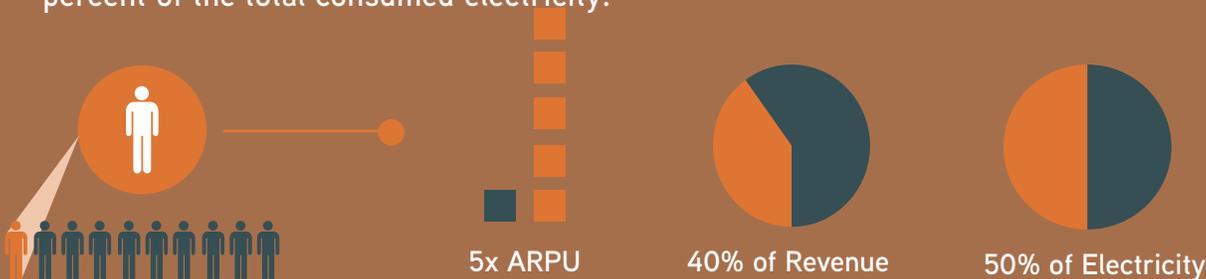


FIGURE 4: ARPU BY SITE

ARPU's vary widely by site.

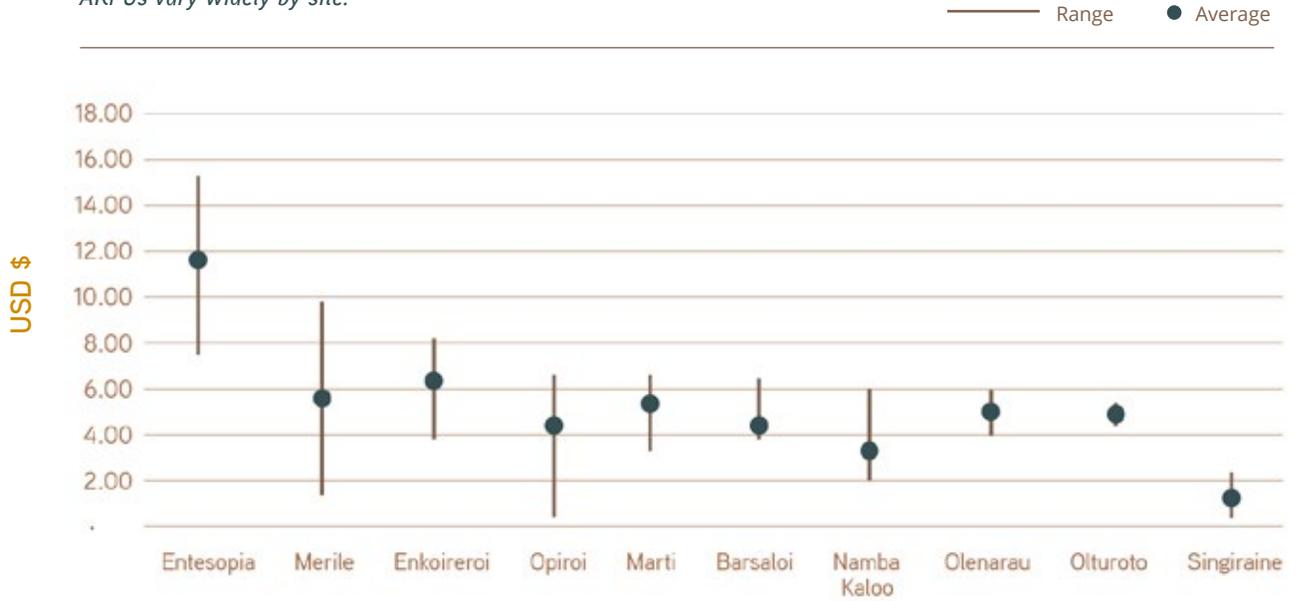
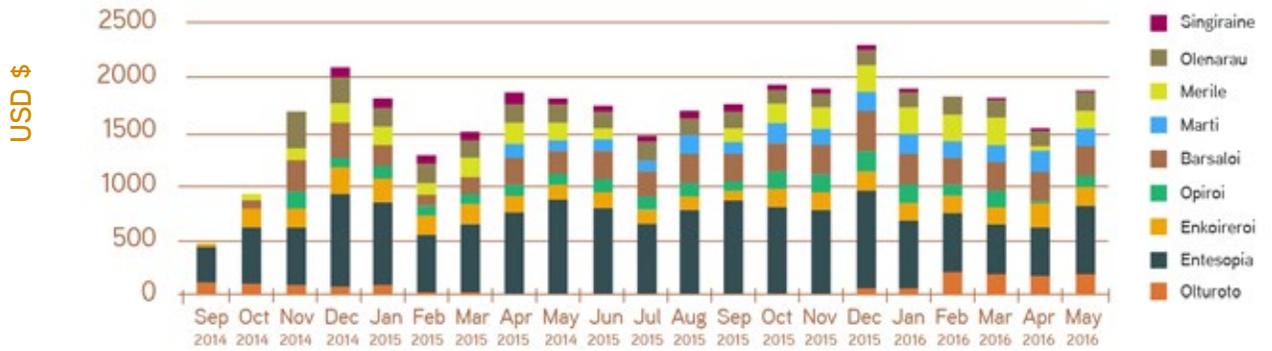


FIGURE 5: MONTHLY SITE REVENUES

The overall trend of revenue was positive, with a 21 percent average variation in total revenues from month to month



## 4.2 Revenue Influencers

Virtually all customers initially used less energy than their pre-installation surveys indicated. The reason is that most people are overly enthusiastic about their potential appliance and electricity use. The customers with greater disparity between expected and actual consumption - indicating a lack of understanding about individual consumption - were in general less satisfied. This potentially further decreases consumption due to dissatisfaction with service. This highlights the importance of customer education and clear, consistent communication via customer service channels.

Fluctuations in currency exchange rates play a significant role in mini grid profitability. We recommend using a financial model that can pull current exchange rates and model these fluctuations across multiple currencies; this will enhance understanding of these fluctuations' impact on the overall financial performance of the mini grid.

### KEY INSIGHTS

Surveyed customers often significantly overestimate how much power they will consume

Customer education is important for customer satisfaction

Fluctuating international exchange rates can significantly affect profitability, so it's important to factor these constant changes into the business model.

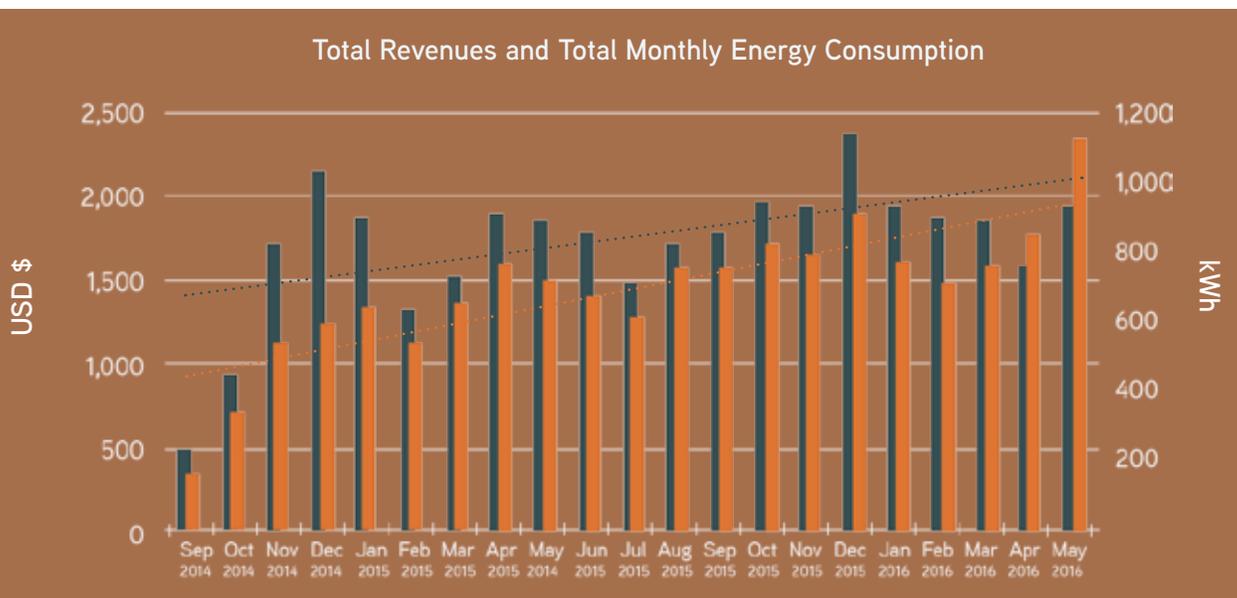
## 4.3 Trends

Our mini grid tariff structure offers economy-of-scale pricing, giving high-consumption customers access to discounts if their electricity usage reaches a certain threshold. Over time, revenue increased; this corresponded with an even greater increase in energy consumption (see FIGURE 7), and a corresponding decrease in the effective tariff as an increasing number of customers opt for volume price incentives.

The average effective tariff over this period was USD \$2.54/kWh; the tariff varied — between USD \$1.80/kWh to USD \$4.00/kWh — depending on what proportion of the revenues came from high-energy or low-energy usage customers, as well as the average payment size. Financial models should account for this, anticipating that margins shrink as revenues grow.

**FIGURE 7**  
*Revenue and Energy Consumption*

■ Total Monthly Energy Consumption (kWh)  
■ Total Revenues (USD \$)



## 4.4 Hourly Distribution

Understanding the anticipated timing of customer energy consumption is important for optimizing system design. FIGURE 8 shows the hourly distribution of energy consumption at the mini grid sites over a typical 1-month period.

Only two of our mini grid sites (Enkoireroi and Singiraine) had higher energy consumption during daylight hours, and this is due to specific circumstances. Enkoireroi has a bi-weekly, day-time market that skews energy consumption 3-4 times higher than non-market days. Singiraine has a unique community layout where businesses are separated from the residential area, and are therefore only active during the day.

For sites like Entesopia, where roughly two-thirds of energy consumption occurs after dark, a large battery bank is critical. With the seasonal consumption fluctuations and variation in solar power generation due to rainy season cloud cover, we expect to replace the battery bank 4-7 times in the system's lifetime.

### KEY INSIGHTS

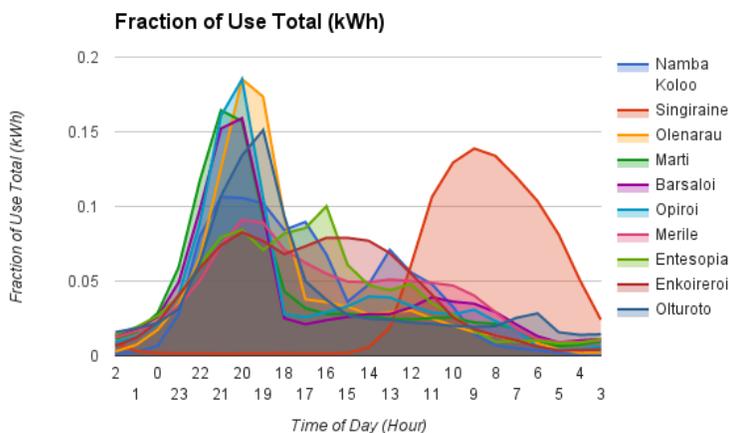
The majority of energy consumption occurs between 6-10 pm

Aligning generation and consumption curves can decrease the system capital expenditure devoted to batteries

Flexible tariffs (e.g. time-of-use) may be a key tool in changing consumption patterns, so Pay-As-You-Go systems that support these tariffs are ideal

### FIGURE 8

*Understanding the anticipated timing of customer energy consumption is important for optimizing system design.*



## 4.5 Remote Monitoring

Evidence suggests that willingness-to-pay is generally dependent on the price of energy as opposed to a flat maximum spend. Economy-of-scale pricing is therefore key to increasing consumption, but must be balanced carefully with the reduction in price to ensure the system protects necessary profit margins. Flexible tariffs which can be remotely adjusted via a remote monitoring system are critical to achieving this balance. Flexible tariffs can also better align energy expenditures with income generation.

Given the strong negative impact of technical issues on revenue, as well as

the high cost of sending technicians to remote field locations, a monitoring system capable of diagnosing and solving simple issues can be an important asset. Technical faults not only reduce revenues by interrupting the normal purchase and use of power, but also erode users' trust and loyalty. That's why it is imperative to resolve issues quickly. At one site, voltage data received from the smart meter allowed operations to diagnose a loose battery connection, which the local site agent fixed at no additional cost, and immediately restored service.

### KEY INSIGHTS

With remote monitoring data and diagnostics, many technical issues can be resolved by a local technician, significantly reducing the cost and time of necessary repairs

Remote monitoring and control systems allow for adjustments in tariffs to help balance supply and demand

## 5. Impact

Energy consumption changed dramatically among mini grid customers in the first 12 months of being connected to the mini grid. Prior to grid installation, the most commonly used energy sources were kerosene and disposable batteries, with 86 percent of customers reporting use of kerosene and batteries. In follow-up surveys, only 4 percent of customers reported using kerosene or batteries at any point during the year (see FIGURE 9). Note that the total percent of respondents is greater than 100, due to people reporting use of multiple energy sources. There is a clear trend of mini grids replacing kerosene, disposable batteries, and diesel generators.

Our data reveals enthusiastic adoption of mini grid services. Customer accounts were "in credit" 84 percent of the time (i.e. there were funds in the account, enabling customers to access electricity). 61 percent of users kept their accounts in credit 100 percent of the time. Designing payment terms that met the needs of low-income rural consumers sparked higher mini grid participation. The average payment amount was USD \$2.00, while the most common payment amount was USD \$0.50. Some customers top up their account multiple times every day, as cash flows into their business.

### KEY INSIGHTS

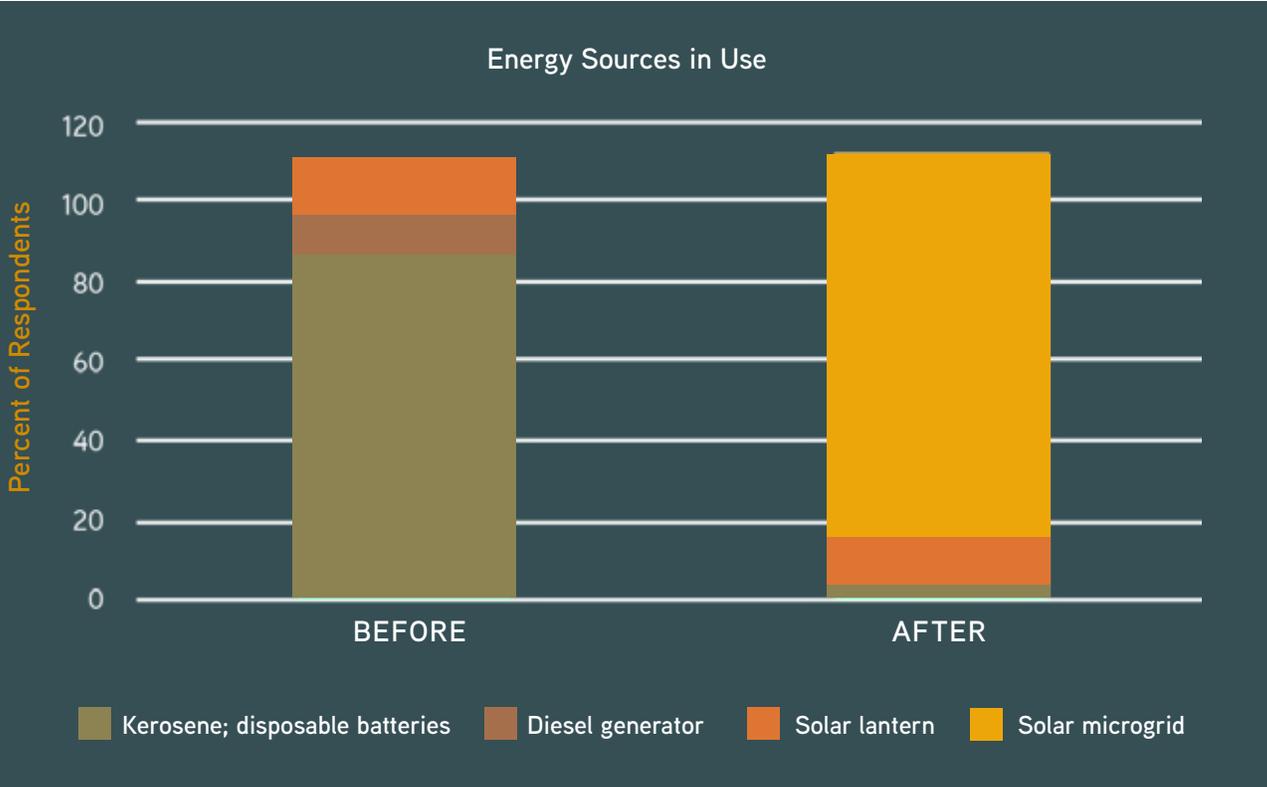
Desire for mini grid electricity is strong. Most customers keep credit in their accounts most of the time

Rural customers are willing and able to pay for electricity access, if payment systems are designed to meet their needs

Centralized electricity access allows for increased economic activity

**FIGURE 9**

*There is a clear trend of mini grids replacing kerosene, disposable batteries, and diesel generators. A switch from fossil fuel use to solar-powered electricity results in improved health, reduced greenhouse gas emissions, cost savings and improved quality of electricity service. Note that the total percent of respondents is greater than 100, due to people reporting use of multiple energy sources.*



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Once connected to the mini grid, customers were quick to take advantage of their access to power. 51 percent of customers connected new appliances, a majority of which were used to improve businesses and generate additional income. Customer surveys confirmed that adding appliances generally translated to greater profitability. 80 percent of surveyed customers indicated their intention was to purchase or lease additional appliances in the future.

The potential impact of mini grids on these communities is significant, as electricity powers new economic opportunities. As climate change negatively influences crops and animal herding patterns, rural communities of Sub-Saharan Africa will be disproportionately affected. Kenya is urbanizing. Cities offer more opportunity for business development, as the national grid can power hair salons, tools, and other energy-hungry appliances. Mini grids enable similar business activities in rural areas, which will help reduce migratory pressure on cities.

In 2017, Vulcan will conduct a quantitative study to better understand the economic impact and social effects of the mini grids. We will share the results when the study is complete.

*One mini grid customer lost almost his entire herd of livestock to drought over the past two years. He described his mini grid connection as a lifesaver, giving him the option of starting a small phone-charging business as a source of income, now that his usual source is gone. Access to clean, sustainable electricity and all that it enables, from affordable lighting to telecoms to refrigeration, will make communities more resilient to the effects of climate change.*

*Another mini grid customer is studying to become a teacher. With his mini grid connection, he has started an entertainment business, showing videos, to cover his school fees.*

*A satisfied customer showing the power outlet in her shop.*



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## 6. What's Next

### 6.1 Continued Data Collection

The mini grids have been operating for almost two years, and emerging trends will become clearer as communities adjust to having electricity. Seasonality has a strong influence on consumption, so we will require multiple years of data to draw accurate, in-depth conclusions about demand growth.

Consumption growth and operating expenditure, along with highly relevant factors that may be out of the operator's control, such as foreign currency exchange rates, are key data points required to establish a sound financial model. A major focus of ongoing data collection and analysis will be establishing more accurate and comprehensive financial projections for the mini grids.

### 6.2 Improving Performance

#### UNDERSTANDING BARRIERS TO INCREASING ENERGY CONSUMPTION

As Vulcan Inc. and steama.co continue to operate the mini grids, we aim to achieve both positive social impacts and profit margins. We limited the cost per kWh of electricity to 20-50 percent less than the cost of generating the same energy from kerosene and diesel fuel. Therefore, the key to improving profitability of our grids is increasing electricity consumption and decreasing operating costs. Consumption at most mini grid sites is much lower than baseline surveys predicted, so improving mini grid profitability will require us to better understand barriers to increasing consumption and how to overcome them. Operating costs will be covered in a subsequent white paper.

As illustrated in **FIGURE 10**, a November 2015 telephone survey of users highlighted the following types of barriers to greater energy consumption:

- Income indicates insufficient income to afford further electricity purchases.
- Demand: Desire indicates that customer demand for electricity has been satisfied
- Demand: Appliances indicates that users would purchase additional electric appliances, but lack the means
- Behavior indicates issues such as a significant overestimate of electricity spend or illiteracy.
- Logistics indicates users who have moved away from their house or who now live in the village only part-time.
- Technical indicates functional issues, such as problems with the electricity line.

Programs to help people afford appliances and customized utility tariff payment plans are being explored as ways to increase energy consumption and financial performance of the mini grids.

#### APPLIANCE PROGRAM

A significant number of users expressed an interest for electric appliances, including refrigerators, microwaves, salon equipment, electric shavers, televisions, lights, carpentry tools, fans, speakers, welding machines, woofers, grinders and mills. The biggest purchase barrier is the high up-front cost and availability. We are exploring options to facilitate affordable access to appliances, which would help maximize system usage.

#### CUSTOMIZED PAYMENT PLANS

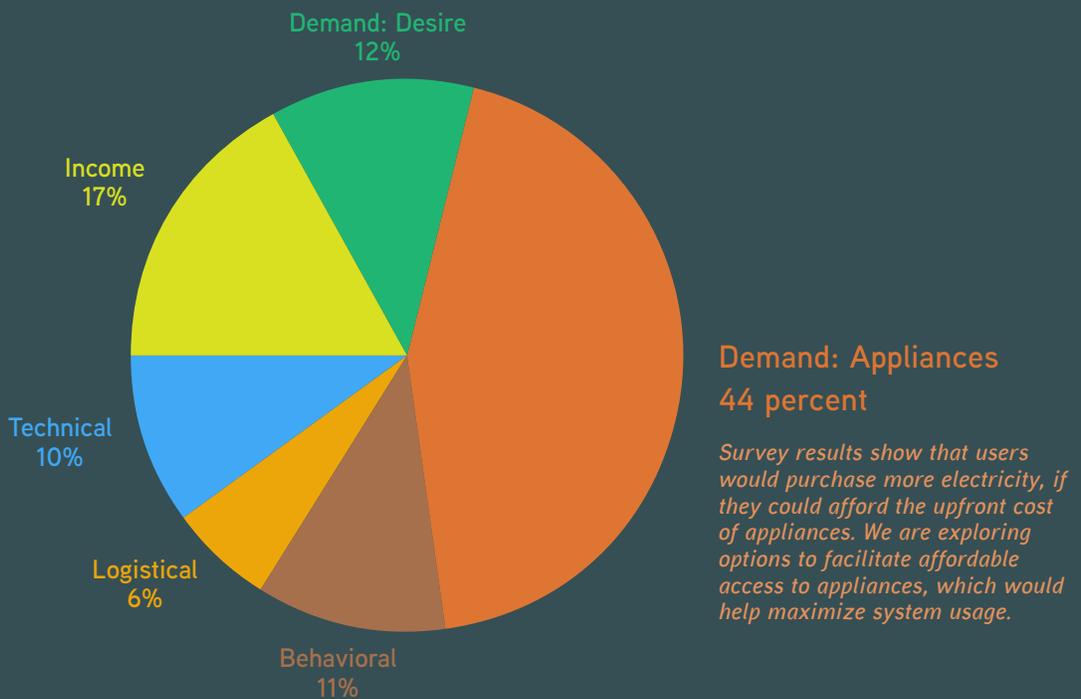
Our studies indicate that an estimated 70 percent of customers are not strictly limited by income or energy consumption. One way to potentially increase energy expenditures would be to customize payment plans to meet customer needs. For example, providing weekly or monthly payment plans for certain customers. To incentivize customers to join these plans, customers would need to understand their benefits, such as a lower tariff, fewer billing-related electricity cut-offs and greater convenience.



Top Left: Steama.co staff member managing construction  
Top Right: Mini grid construction

### Figure 10 : Barriers to Increasing Energy Consumption

Improving mini grid profitability will require us to better understand barriers to increasing energy consumption and how to overcome those barriers



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## 6.3 Future Publications

Our next white paper will explore the financials of our mini grid installation and operation, especially on day-to-day operating costs. As previously mentioned, we'll conduct a study on the economic and social impact of the sites, including a reflection on the sites chosen for commercial value versus the sites chosen for impact value. We are also collaborating with university researchers to do a deeper analysis of the mini grid data, most likely with a focus on demand estimation methods.

*“I used to lose a lot of fuel by using calibrated containers... plus a lot of it would go to waste via evaporation while in the jerricans, but with power available, I now simply use the automated machine.”*

*Jane Musyoka  
Entesopia Resident*

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## 7. Conclusion

Our experience has led us to believe that commercial mini grids have the potential to be profitably operated while also making a positive impact on the lives of rural customers. Some of the levers for profitability that we've found are careful site selection and grid design, recruiting the right mix of customers, and other factors affecting ARPU and revenue. As the cost of solar panels, batteries and other components of the mini grid systems continue to decline, and innovative business models and financing mechanisms emerge, the opportunity for commercial success continues to grow.

*Mini grid customer with a welding business*



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## PAUL G. ALLEN'S COMMITMENT TO AFRICA

Paul G. Allen tackles some of the world's hardest problems, using technology and data to catalyze innovation, improve policy and accelerate change. Paul has been active in Africa for many years, and has invested a great deal to improve public health, fight infectious disease, protect elephants and develop sustainable tourism that advances conservation and benefits local residents. He's also investing in scalable business models that provide village-level infrastructure for underserved communities. He believes that empowering African entrepreneurs will strengthen economic and social resiliency, and it is this belief that inspired him to invest in pioneering solar mini grids.

### Vulcan Impact Investing

Vulcan Impact Investing (VI2) identifies and invests in market-based solutions that have the potential to transform lives through sustainable, scalable approaches to development. VI2 supports businesses which accelerate access to infrastructure and services designed to meaningfully improve quality of life.

VI2 bridges the gap between founder and venture capital funding. We are specifically interested in projects or companies:

- Based in Sub-Saharan Africa with a focus on Botswana, Kenya, Tanzania and Zambia
- Focused on enabling infrastructure—mainly last-mile, off-grid electrification, connectivity, sustainable heating and heating fuels
- With the potential for scalable and enduring impact for at least one million people
- With a demonstrated proof-of-concept and clear, compelling business plan

VI2 is led by Lauren Kickham, who has more than 12 years of experience in business, investing and sustainable enterprise and infrastructure in Africa. Courtney Blodgett, who manages VI2's pipeline development, has nearly a decade of experience working in Africa implementing innovative finance models for impact-oriented businesses. A special acknowledgement to Dan Prull, an energy consultant for Vulcan through 2015, who was instrumental in the design, planning and early stage operations of the mini grids. VI2 can be contacted at: [VI2@vulcan.com](mailto:VI2@vulcan.com). Further information is available at [www.vulcan.com/VI2](http://www.vulcan.com/VI2).

### Steama.co

Steama.co enables companies to sell clean energy in remotest Africa. Today there are 3 ways to get electricity to off-grid towns—grid extension, solar home systems and mini grids. steama.co is focused on solar mini grids—because they are rapid to deploy and provide 24h grid-quality power at reasonable prices.

Steama.co's universal smart meter is affordable, simple and robust. Its devices send data up to the cloud wirelessly. Steama.co's cloud software crunches the data, processes payments and sends instructions back to the real world to physically switch power, water and fuel on or off. This happens within seconds, 1,000s of times a day, in places where you can't even make a phone call.

Mini grids come in all shapes, sizes, locations and business models. Steama.co's technology handles all the billing complexity. It automates large mini grids that power off-grid towns, and equally small solar irrigation pumps for individual farmers.

Steama.co's executive team includes cofounder and CEO Harrison Leaf, cofounder and CTO Sam DUBY, and CFO Tom Parkinson. Management is supported by non-executive directors Peter Gutman, Andrew Reicher, Ian Nolan and George Potts. Emily Moder is the VP of Operations. Steama.co can be contacted at [enquiries@steama.co](mailto:enquiries@steama.co). Further information is available at <http://steama.co/>

