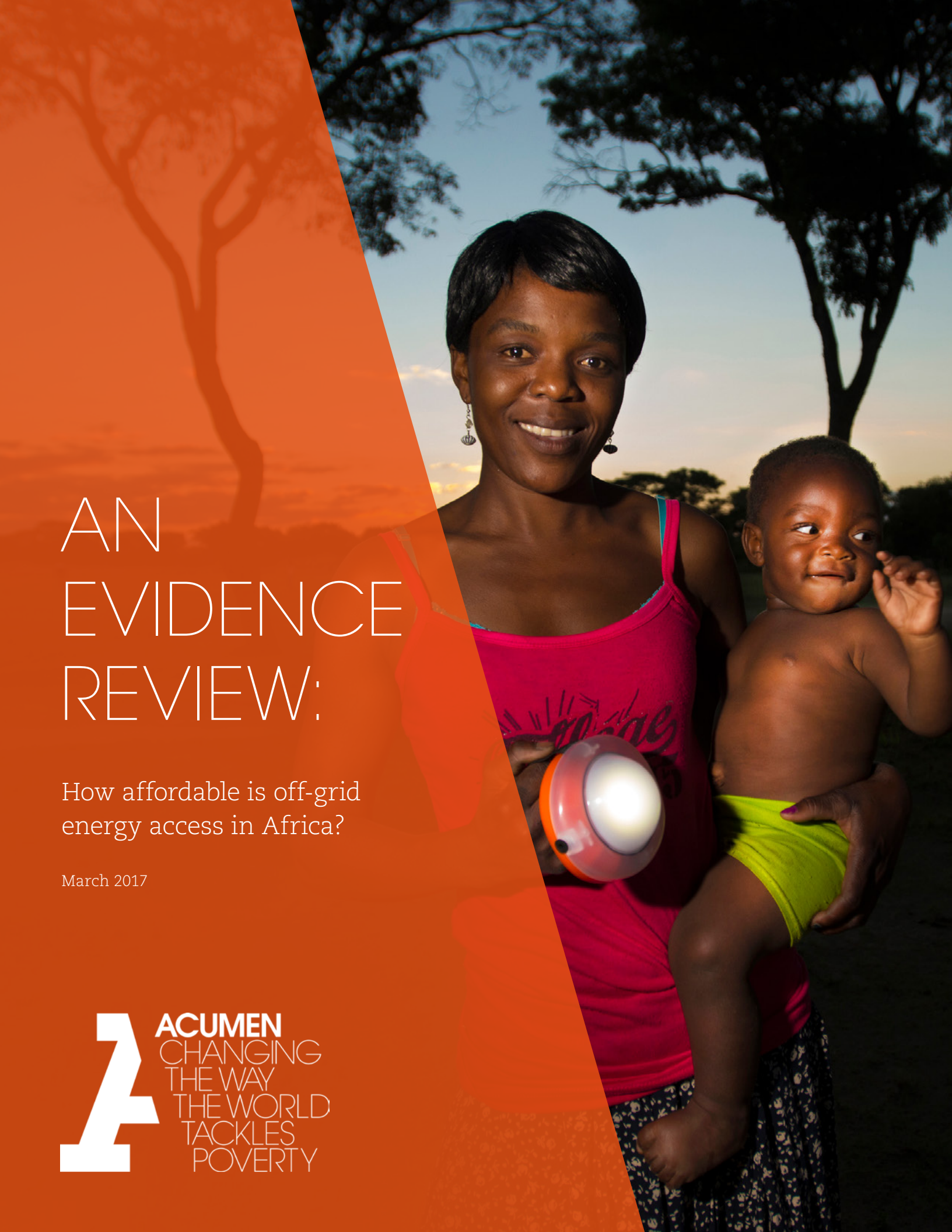

AN EVIDENCE REVIEW:

How affordable is off-grid energy access in Africa?

March 2017

ACUMEN
CHANGING THE WAY THE WORLD TACKLES POVERTY

AUTHORS

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ABOUT

This report was commissioned by CDC Group and prepared by Kat Harrison and Tom Adams of Acumen. The views presented in this paper are those of the authors and do not necessarily represent the views of CDC.

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EXECUTIVE SUMMARY

This report provides a review of the evidence of the affordability of energy access in sub-Saharan Africa (SSA).

It includes information drawn from a combination of an extensive literature review, early insights from Acumen's Energy Impact Series1, and direct-consumer based data collected by Acumen and SolarAid.

While this report was commissioned to look at affordability of energy more broadly it has in large part focused on off-grid solutions and solar in particular. This is for two reasons. First, access to established grid-based energy covers less than a third of the population of SSA. Second, in the off-grid space, solar is leading the way compared to other modern alternatives in terms of reach and ability to distribute. We believe that many of the lessons from the solar sector will be transferable to other energy solutions. A mixed approach is the only way energy access goals will be reached and this will include both grid and off-grid, and options beyond solar. Though access to energy for cooking is a critical area of energy consumption energy use for cooking is a very specific and separate sub-sector and we have not looked in any detail at sectors such as clean cookstoves.

The report covers the following. First, a brief background of the energy access problem and a snapshot of what is known about markets for energy access across SSA. Second, an analysis of affordability based largely on observed spending patterns and income levels of consumers. Third, an assessment of the availability and efficacy of financing to improve energy access. Fourth, a look into some of the wider considerations beyond affordability that affect adoption of energy access. Finally, recommendations for further research to address some of the gaps in knowledge.

1. A series of monthly articles featuring insight from the suite of energy evaluations we are currently undertaking to complement our Lean Data approach. The introduction can be found here

2. Pico-solar lights are small, portable solar lights that provide a single light point, often with an integrated panel, and sometimes with mobile phone charging capacity.

Global energy access is a challenge for our time

1.2 billion mostly poor, mostly rural people live without electricity across the world today. Lack of energy access disproportionately affects the poor. It harms their prospects of working their way out of poverty, forces them into the paradox of spending up to one hundred times more than those in developed countries on inferior energy products, and exposes them to life-threatening indoor pollutants. The introduction of the Sustainable Development Goals (SDGs) in 2015 brought focused attention to the question of energy access. Goal 7 focuses on achieving access to affordable, reliable, sustainable and modern energy for all by 2030.

SEVEN EARLY INSIGHTS ON AFFORDABILITY & ADOPTION

+ Poorer households appear to spend a relatively larger share of their total expenditure on energy than wealthier families.
+ There are indications that consumers are fairly price sensitive (demand is price elastic).
+ The poor are generally accessing solar where it is available, but only pico-lights are reaching the extreme poor.[2]
+ Consumers want financing, and offering it may help drive sales. However, customers may not always understand what they're signing up for.
+ Lack of both product awareness and trust still presents a challenge for adoption.
+ Customers typically state a combination of access to more and brighter light, improved energy reliability, and reduced expenditure as the most important benefits of solar products.
+ Access to solar is increasing rapidly but it is highly concentrated in a few countries.

Energy markets in sub-Saharan Africa

Of the 1.2 billion people without energy, half of these live in Africa. The International Energy Agency (IEA) reports that SSA remains the only region in the world where the number of people living without electricity is actually increasing. Overall Africa currently has 147 gigawatts of installed capacity, a level comparable to the capacity China installs every 1-2 years. In 37 of the 49 countries of SSA the number of people without electricity has increased since 2000. Even these depressingly low numbers tell only half the story. Even where people can access energy, prices for grid-based connection across SSA are disproportionately high and energy reliability low.

Solar energy has the potential to close the energy gap

However it is not all doom and gloom. According to The Economist the recent growth of the solar market has led to an estimated 600,000 households in Africa gaining access to modern energy for the first time in the form of solar home systems (SHS).[3] In terms of total sales the market has been led by pico-solar lights[4], but business model innovations such as pay-as-you-go (PAYG) financing are now attracting much of the limelight. In theory they should lead to improved accessibility and affordability of higher capacity systems. Industry experts predict the number of home-power systems on African roofs to double in 2017 alone. A growing number of businesses are emerging to serve and scale this market

Solar is increasingly in reach of poor consumers

The growth in solar has been driven by a dramatic reduction in production costs - down 80% since 2010 and likely to fall further - alongside continued technological improvements. In Kenya, for example, an average small-scale solar home system costs in the region of US$120. This is roughly equivalent to 5% of a poor family's total annualised income.[5] Given that estimates of average household spending on energy - predominantly lighting and phone charging - range from 3-15% of total income, solar purchases can represent an attractive household level rate of return. SolarAid research has found that households purchasing entry-level or pico-solar energy products are able to recoup the cost of the product from reducing spend on alternative sources of lighting within a time period of 10 weeks.

The price falls have brought solar products within the reach of the poor for the first time. Pico-solar lights have penetrated deep into African markets. SolarAid data from Kenya, Malawi, Tanzania, Uganda, and Zambia shows that of customers buying the simplest solar-powered lights costing around $10, 82% live below the $3.10 poverty line. Acumen's data, collected using the Progress out of Poverty Index, has shown similarly encouraging ability of companies to reach poorer consumers. Using weighting from sales, 36% of the customer base of five SHS and mini-grid companies across four East African countries lives below the poverty line at $3.10 per person per day.[6] It is, of course, hard to draw concrete conclusions from such a small number of data points, but if any conclusions could be drawn, it would be that only pico-lights are currently reaching the extreme poor in a meaningful way. Beyond that, penetration may have as much to do with the available customer base as it does product type.

Customers are price sensitive

Recent research has shown that demand for pico-solar products is fairly price elastic. The same research also discovered, not surprisingly, that poorer households spend a relatively larger share of their total expenditure on energy, but as families become wealthier, energy expenditure falls as a proportion of total expenditure. The poorest quintile of Kenyan customers spent ~10% of their total expenditure in energy compared to the average across all households of ~5%. This is building a picture of a keen, yet price-sensitive customer and also that targeting deep into the base of the pyramid may be a promising marketing strategy.

Customers want financing, but are not always financially literate

Along with efforts to drive down prices, considerable attention has been paid to financing as a way of making access to more powerful energy products more affordable. Acumen's data suggests that financing is an attractive option for customers. For one SHS company, 53% of customers said that the reason they selected the company was the financing on offer (just 3% commented on price). SolarAid piloted PAYG for pico-solar lights in Kenya in 2015 and found purchase rates for entry-level solar lights increased from 10-15% of targeted customers to 20-50%.

3. The Economist, 2016. Africa Unplugged. The Economist.
4. Pico-solar lights are small, portable solar lights that provide a single light point, often with an integrated panel, and sometimes with mobile phone charging capacity.
5. Calculated by converting the $120 absolute price into a PPP-adjusted price, dividing it by $3.10 a day then multiplying by 5 people in a household over 365 days.
6. Kenya, Rwanda, Tanzania, Uganda.

Although financing is generally appealing, it is not without its challenges. The presence of high deposits - typically 10-30% of the fully financed cost of the solar product - may remain a barrier to affordability. Customers purchasing on credit also run the risk of experiencing financial difficulty. Acumen has seen mixed evidence of self-reported repayment issues, from 8% for customers of one company in East Africa to 28% for another in India. A separate study in Rwanda even found that as many as 52% of consumers reported struggling with the regular payments. There is evidence that customers can find the contracts involved in PAYG confusing. According to data collected by Acumen for one company, 27% of customers felt that the agent did not explain the contract to them adequately, and 13% said that parts of the payment plan were unclear.

Reasons for adoption beyond affordability

While this study was commissioned to look at affordability, the price of a product or the availability of financing are not the only influences on the decision to buy or connect. A framework developed by Acumen and Bain & Company describes adoption as driven by the 4As: Awareness, Advantage, Access, and Affordability.

Awareness represents both the knowledge of a product or service and also of how to use it most effectively. An Acumen Lean Data study with unconverted leads of a SHS company found that the most common reason for a lack of adoption was lack of information on the product (affordability came in second). An earlier SolarAid market study saw that awareness of pico-solar lights varied greatly throughout different markets with 96% of respondents knowing about solar lights in Kenya, 88% in Tanzania, 47% in Zambia, 38% in Malawi, and just 20% in Senegal. Though the market has progressed since this time this shows that even relatively recently awareness has been surprisingly low.

In terms of perceived advantages (relative to competing energy options) Acumen's Lean Data work has found that customers identify having access to more and brighter light, improved energy reliability, and reduced expenditure as the most important benefits of solar products. Feeling more secure/safe, as well as healthier, cleaner, and happier in one's home are also mentioned though less often.product type.

Challenges in access are mixed but improving rapidly. In Kenya, SolarAid found that knowledge of where to buy a solar light has increased rapidly over the past two years, from 31% to 75%. The estimated distance required to travel to purchase a solar product fell from 63 to 4km. In Tanzania, consumer awareness of where to purchase increased from 15% to 49% over two years.[7] We also discovered that distributors complain about their inability to maintain sufficient stocks and report a lack of agent-financing restricting their opportunity to market and sell solar products.

Gaps in available evidence and recommendations for study

This report summarises what we know about the factors affecting affordability of energy access in Africa for low-income households. What is clear is that although a picture is emerging, it remains a relatively sketchy one. In our search we found little prior research specifically on affordability. We also found little information on energy access beyond decentralised solar energy and some limited information on grid pricing. As a consequence we have, at times, had to rely on related data, broader evidence, and extrapolated conclusions to provide the insights within this report. We believe that a specific initiative to gather multi-country data and perspectives direct from both current and potential consumers would yield significant further insight. In particular we believe this would help test some of the following research questions and hypotheses:

+ Hypothesis 1: the poverty reach of energy products declines as we move up the energy ladder.
+ Hypothesis 2: low income customers are at greater risk when accessing credit.
+ Hypothesis 3: affordability is not the most important driver of adoption.
+ Hypothesis 4: women consume and value energy differently from men.

Additionally, there is scope to further explore types of energy access beyond off-grid solar, which this

report focuses on, somewhat, due to even more limited data, research, and information.

7 SolarAid (2015). Baseline and follow up market research. 3,500 respondents over 45 markets.

CONTENTS

1. INTRODUCTION: WHAT IS THIS REPORT ABOUT?

Purpose of this report

This report has been commissioned by CDC to consider the current state of affordability in the energy sector, with a focus on Africa. Whilst there is, justifiably, significant excitement about the growth of off-grid energy surprisingly little is actually known from a consumer perspective about affordability, and with low levels of grid electrification, often even less known on this. This report sets out to investigate questions such as: is affordability of products in the sector a problem; what factors affect affordability; do products targeting poorer segments of society, actually reach these consumers, including whether there are any differences in affordability by gender; and what mechanisms, if any, have companies used to improve the affordability of energy products and services?

A focus on solar

While this report was commissioned to look at affordability of energy more broadly it has in large part focused on off-grid energy and solar in particular. This is for two reasons. First, access to established grid-based energy covers less than a third of the population of sub-Saharan Africa (SSA). Second, in the off-grid space, solar is leading the way compared to competing modern alternatives in terms of reach and ability to distribute. Consequently considerably more has been written about solar and we have collected significantly more data within this sub-sector. Even so, we believe that many of the lessons from solar will be transferable to other off-grid energy solutions. In addition, a mixed approach is the only way energy access goals will be reached and this will include both grid and off-grid, and options beyond solar. Similarly, this report focuses on energy use for lighting, phone charging and the powering of small appliances. Though access to energy for cooking is a critical area of energy consumption energy use for cooking is a very specific and separate sub-sector and we have not looked in any detail at sectors such as clean cookstoves.

Approach taken and availability of evidence

To find answers to the questions above the authors have drawn from a combination of extensive literature review, early insights from Acumen's Energy Impact Series,[8] and direct-consumer based data collected by Acumen and SolarAid. Specifically data drawn from work undertaken at Acumen and SolarAid which together has interviewed close to 40,000 energy users across Africa over the past four years. Much of this data, and especially the findings of the literature review, were not specifically focused on the question of affordability itself. As a consequence some of the analysis relies on proxies and inference. We make suggestions on the sort of data that could be collected to more directly build our knowledge of affordability.

What do we mean by affordability and how is it best measured?

Before going further, let's define what we mean by affordability. Affordability is subjective, dependent on multiple factors and is influenced by both internal (to the person) and external (of the environment) elements. It will be affected by price but is also determined by someone's available resources, their prioritisation for spending, and their perceived value of a product or service over its lifetime.

In terms of measurement, we found no specific frameworks for affordability per se. Clearly organisations are taking assessments of affordability all the time and these tend to focus on analysis of incomes earned and expenditure patterns (e.g. mortgage applications). Companies that sell energy products via financing often have their own proprietary credit worthiness assessments. The authors do not recommend that CDC try to develop its own affordability framework. However one framework we have applied considers factors that drive adoption that include, but also go beyond affordability. Acumen developed the 4As - awareness, access, advantage and affordability - alongside Bain & Company We have previously used it to access uptake of agricultural innovations, and we apply it to energy here.

8. A series of monthly articles featuring insight from the suite of energy evaluations we are currently undertaking to complement our Lean Data approach. The introduction can be found here

2. SETTING THE SCENE

A BRIEF BACKGROUND TO THE SECTOR

The energy access challenge

The numbers are stark. Today, a staggering 1.2 billion mostly poor, mostly rural people live without electricity around the world. Globally two in every five people have to rely on wood or other biomass to cook and heat their homes. And although a huge 1.7 billion people obtained connections to electricity between 1990 and 2010, this rate was only slightly higher than the growth in population of 1.6 billion over the same period. Even those who do live with electricity are often underserved, typically having access to unreliable or inadequate grid connection.

Lack of energy access disproportionately affects the poor and limits opportunities for economic development. It cuts the productive day short, forces families to spend more for lower quality services, and exposes them to dangerous lighting alternatives such as kerosene lanterns, candles, and torches. Kerosene lamps – used by an estimated 290 million people across Africa – contribute to indoor air pollution, the effects of which kill more people than tuberculosis, malaria and HIV annually.[9] Such lamps also emit high volumes of carbon dioxide and black carbon, the top two climate warmers.

Those living without national grid connections, 'off-grid', are typically buying lighting at the equivalent of $100 per kilowatt/hour, more than a hundred times the amount people in higher income countries pay.[10] One estimate suggests that the world's off-grid households spend approximately $40 billion per year on lighting, around 20% of all global lighting expenditures, but enjoy a meagre 0.1% of the available light.[11] In aggregate, it is estimated that African low-income households are spending around $6.5 billion a year on predominantly poor quality lighting.[12]

Sustainable Development Goal 7

While not included in the Millennium Development Goals (MDGs), the introduction of the Sustainable Development Goals (SDGs) in 2015 placed energy access squarely on the development agenda. SDG7 focuses on achieving access to affordable, reliable, sustainable and modern energy for all by 2030. It aims to do this by investing in energy generation, transmission and distribution; doubling the rate of improvement in global energy efficiency to save energy, money, and emissions; and doubling the share of the world's mix of renewable energy, including phasing out untargeted fossil fuel subsidies, as well as establishing a price for carbon and price incentives for renewables.

Investment in grid infrastructure

The emergence of SDG7 reflects both an acknowledgement of the scale of the problem and also a recognition that our approaches to date have either not worked, or not worked quickly enough. Traditional approaches – largely investment in large-scale, grid-based power supply – have had a mixed history. In some geographies, it has been transformational, in others success has been muted. Where investment in grid energy falls short the causes are typically a combination of capital limitations, poor regulation, missing domestic energy markets, uneven population densities, and corruption. The World Bank estimates that growth in electricity expansion will have to double to meet the 100% access target and getting there by 2030 and will require an additional $45 billion invested every year, five times the current level.[13]

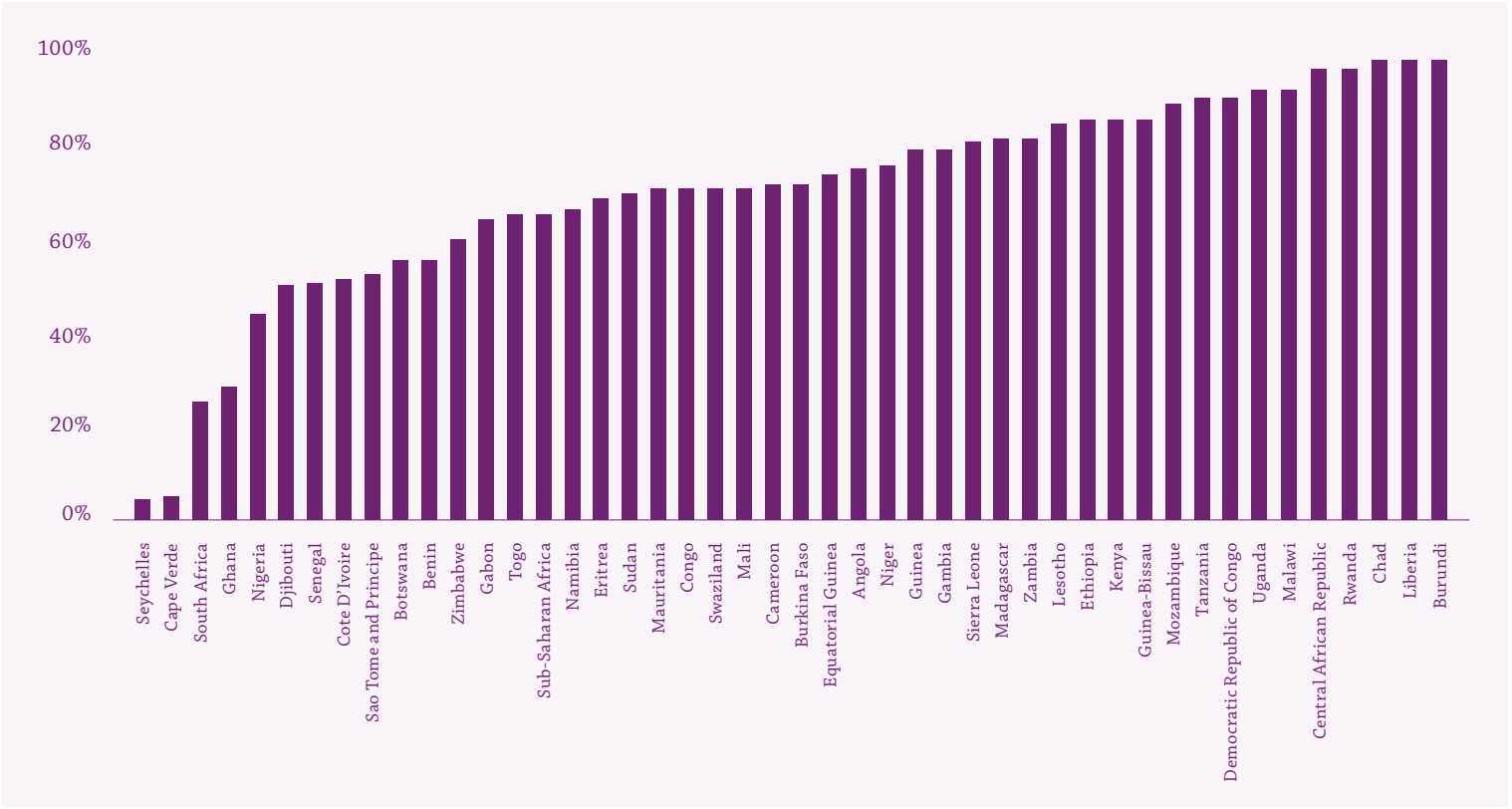
9. World Health Organisation (WHO) (2012). Burden of Disease from Household Air Pollution
10. The Economist (2015). A brightening continent
11. Mills and Jacobson (2011). From Carbon to Light
12. Harrison, Scott, and Hogarth (2016). Accelerating access to electricity in Africa with off-Grid Solar
13. World Bank (2013). Global Tracking Framework

Energy access across sub-Saharan Africa

Of the 1.2 billion people without energy, half of these live in Africa. The IEA reports that SSA remains the only region in the world where the number of people living without electricity is actually increasing.[14] Overall Africa currently has 147 gigawatts of installed capacity, a level comparable to the capacity China installs every 1-2 years.[15] In 37 of 49 SSA countries the number of people without electricity has increased since 2000. Only countries such as Nigeria, Ethiopia, South Africa, Ghana, Cameroon and Mozambique are bucking the trend.[16]

Even these depressingly low numbers tell only half the story. Where grid-based energy is available the price of connection is often out of reach of consumers. Connection charges in Africa range from $2 to $400, and regularly exceed a household's average monthly income.[17] The outcome of this has been that even when villages had been connected for 15-20 years, it was common for a quarter of households to remain unconnected.[18] When households are connected, the tariffs for electricity remain high. The chart below shows the average retail power prices for grid access, also highlighting that in countries including Senegal, Ghana, Rwanda, and Malawi prices have been increasing.

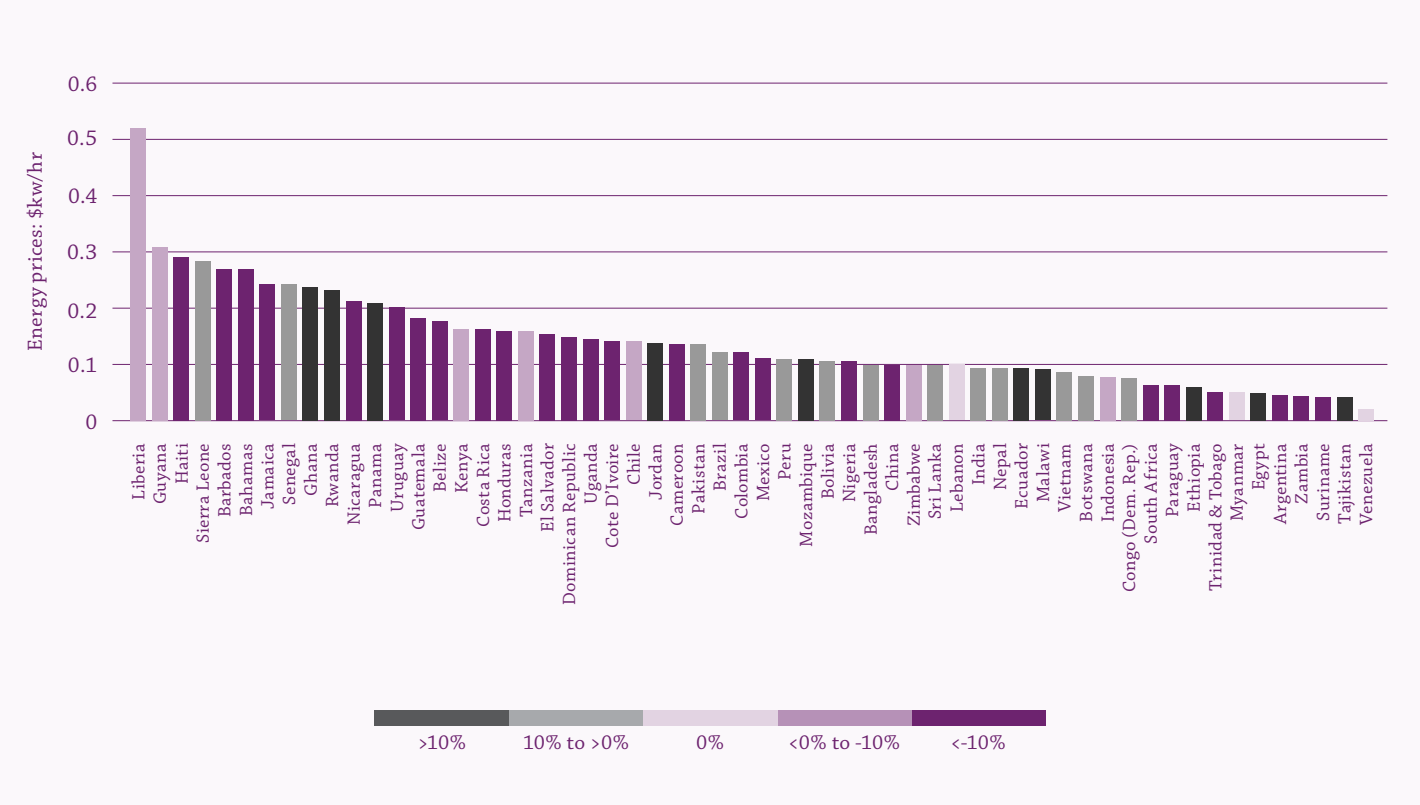
Share Of Population Without Access To Electricity (%)



Source: IRENA

14. International Energy Agency (IEA) (2014). Africa Energy Outlook: A Focus on Energy Prospects in Sub-Saharan Africa
15. International Renewable Energy Agency (IRENA) (2012). Prospects for the African Power Sector
16. IEA (2014). Africa Energy Outlook: Special Report
17. Harrison, Scott, and Hogarth (2016). Accelerating access to electricity in Africa with off-Grid Solar
18. World Bank (2008). Project Assessment Report Lao People's Democratic Republic Southern Provinces Rural Electrification Project

Variation in price between 2013 and 2015



Source: ClimateScope

The rise of solar

Increasingly the decentralised energy sector is being championed as a solution to providing power to those living off-grid. The International Energy Agency (IEA) estimates that by 2040 mini-grids and off-grid systems will provide electricity to around 70% of rural populations.[19] As costs of components tumble and the technology improves, solar is emerging as the frontrunner among competing off-grid solutions. A trend that is expected to continue.

The major advantages of solar – compared to biomass, hydro, and wind power – are as follows. Solar as a fuel can be used almost anywhere, whereas wind and hydro power cannot. Wind power tends to be large-scale and to generate energy for the grid, thus is often dependent on grid extension and requires greater sums of capital investment. Solar panels typically have higher efficiencies than biomass plants and distributed solar companies have demonstrated greater potential to be commercially viable and face fewer operational complexities compared with biomass (shortages, commoditisation) and hydro (location, operational feasibility). Solar is also lend itself more easily to a modular approach meaning it is more adaptable to both large and small energy needs, especially important in less densely populated rural settings. While off-grid energy access does not equal solar energy only, because this particular innovation is so clearly leading the way it inevitably means we focus our analysis heavily on solar in this report.

Today, over 44 million solar products have been sold around the world, the majority of which are in rural Africa and are typically small products known as pico-solar.[20] This, simple form of solar, usually provides a portable light, sometimes with capability to charge a phone. There is also significant growth in relatively more expensive solar home systems (SHSs) which have more power, offer multiple light points and the ability to power a variety of appliances. Although more expensive, with access to credit, households can spread cost of ownership of SHSs over a payment period, or they can access energy services through a more traditional utility model. Pay-as-you-go (PAYG) SHSs have attracted an unprecedented level of interest within the sector.

These varying products have often been represented as an "energy ladder", describing gradual increases in energy consumption. Strictly speaking the energy ladder is about capacity for a household rather than the source of energy. However, the ladder is often used to describe a product scale with pico-lights on the first rung, moving up to solar kits, SHSs, mini-grids, and then the grid. Another similar (though less widespread) representation is that of a staircase where households 'stack' their energy use. This is likely more accurate, since families tend to supplement rather than displace existing energy sources as they consume larger or multiple systems.

For now solar is winning, but storage – especially for night-time electricity – remains an issue. Current batteries are typically the least durable part of any system (i.e. the battery fails before the panels themselves) and are often not large enough to store power needed for larger appliances like fridges. Trends here look generally positive: lithium-based batteries and flow batteries are able to store more power and for longer periods than older nickel-based batteries. Even so, the cost of batteries continues to be a pain point, and a further reduction will be key for increased adoption of more powerful solar.[21]

Current market players

Given the widespread absence, unreliability, or high cost of grid-based energy, energy markets across SSA are prime candidates for more affordable, reliable alternatives. Traditionally this demand for energy has been met by fuels like diesel and kerosene but as outlined above solar is establishing itself as a credible clean alternative. Indeed, increasingly even families connected to the grid are purchasing solar home systems as either backup or substitution to the grid. Using Acumen's own Lean Data[22] approach, we found that for one SHS company in East Africa as many as 15% of their customer base were already connected to the grid.

19. IEA (2014). Africa Energy Outlook: A Focus on Energy Prospects in Sub-Saharan Africa.
20. Bloomberg New Energy Finance (BNEF) (2016). Off-grid Solar Market Trend Report 2016.
21. Acumen (2016). Pioneer Energy Investment Initiative White Paper.
22. More can be found on Lean Data here.

> I bought [the SHS] because of black out that we normally have. Sometimes we go without power for three days and that is a problem because there is no way even to charge a phone.
>
> – Kenya

From an industry that barely existed a few years ago it is now thought that solar home systems are providing access to energy to around 600,000 households in Africa.[23] The market for slightly more powerful systems is growing most rapidly, while that of entry-level handheld devices has seen a decline. Globally, reported unit sales of 3-10 watt multi-light solar systems have increased 5-fold over the past year, while conversely, there has been a decrease in sales of 0-3 watt single light products.[24] Industry experts predict that the number of power systems on African roofs could double again in 2017 alone.

M-KOPA, the market leader in SHSs, has installed 400,000 of their systems to date. At its current rate of growth it may add another 200,000 to that number in 2017. Smaller rivals such as Off Grid:Electric and Azuri Technologies may well double their client base over the same period.[25] These exciting companies have developed with varying business models including: distributor-dealer channels, proprietary distribution, franchise models and rental or leasing systems.

However the spread of solar across Africa is far from even, with a concentration of companies in East Africa. Data from the Global Off-Grid Lighting Association (GOGLA) suggests that East Africa represents about 70% of total sales volume in Africa and 77% of revenues.[26]

Bloomberg New Energy Finance found that pay-as-you-go SHS companies are most prevalent in Kenya, Tanzania, Rwanda and Uganda with leaders such as M-KOPA, mobisol, Off-Grid:Electric, Fenix International and BBOXX having established operations.[27] The list below shows the main players in some of the markets of Africa.

+ Kenya: M-KOPA, d.light, BBOXX, SunnyMoney, Orb Energy, SunTransfer, Greenlight Planet
+ Uganda: Fenix International, BBOXX, SolarNow, Azuri, M-Kopa, Village Power, SunnyMoney, d.light, Greenlight Planet
+ Rwanda: d.light, BBOXX, mobisol
+ Tanzania: mobisol, Fenix International, M-KOPA, Off-Grid Electric, Eternum energy, EEG energy, Devergy
+ Senegal: Oolu Solar
+ Sierra Leone: Azuri
+ Togo: Azuri
+ Malawi: Azuri, SunnyMoney
+ Zimbabwe: Azuri
+ Nigeria: Nova Lumos
+ South Africa: Azuri, Kingo
+ Ethiopia: Azuri
+ Zambia: SunnyMoney, Vitalite

Moreover even where consumers can access solar, they are often confronted with limited choices. Acumen's own data collection shows that for two solar home system companies offering credit for purchase of SHS in East Africa, more than 9 out of 10 customers said they could not find an alternative to the service they purchased. Lack of choice may mean that households are unable to find the most suitable product or service for their needs or budgets. Choice options tend to dwindle the further consumers are from urban areas.

23. The Economist (2016). Africa Unplugged.
24. Global Off-Grid Lighting Association (GOGLA) (2016). Global off-grid Solar Market Report
25. The Economist (2016). Africa Unplugged
26. GOGLA (2016). Global off-grid Solar Market Report. The equivalent numbers for South Asia show an even greater concentration, with 1.72 million units sold from a total of 1.76 units sold in India.
27. BNEF (2016). Off-grid Solar Market Trend Report 2016.

Public pricing information for a selection of industry leaders[28]

Organisation: Greenlight Planet
Number of installations (households): 5,025,695
Areas of operation: Global
Employees: not shared
Princing: from $8 for their pico-solar light to $109 for their home system. They have also created capability for distributors to sell through instalments with a platform embedded in the products.

Greenlight Planet design and manufacture a range of solar lights from the PICO to the HOME 120, all branded Sun King. They work through distributors and sell some of their own products too.

Organisation: SunnyMoney
Number of installations (households): 1,890,000
Areas of operation: Malawi, Uganda, Zambia (previously: Kenya, Tanzania, Senegal)
Employees: 50
Pricing: Selling mostly pico-solar lights from $5-35 depending on capability.

SunnyMoney is the social enterprise of UK charity SolarAid. They were the biggest seller of pico-solar lights for many years, distributing manufacturer products including d.light and Greenlight Planet. They have just produced their own solar light, the SM100, funded by Yingli.

Organisation: M-KOPA Solar
Number of installations (households): 400,000
Areas of operation: Kenya, Uganda, Tanzania
Employees: 800
Pricing: Customers pay an initial $35 deposit, followed by 365 daily payments of $0.45. In return, they receive a solar home system that includes multiple lights, a phone charger and a radio. Total price paid: $199.25.

M-KOPA uses a pay-as-you-go system integrated with the M-PESA mobile money platform. This allows customers to buy solar power on a monthly, daily, weekly or even hourly basis.v

Organisation: Azuri
Number of installations (households): 100,000
Areas of operation: Global
Employees: 400+
Princing: Kenyan customers pay $10 deposit, weekly payments between $2.50-$3.50 per week for 50-70 weeks. Total price paid: $130-180.

The company's entry level PayGo solar system provides users with eight hours of lighting daily. The Azuri PayGo solar product portfolio includes the first complete PayGo satellite TV package targeting households without electricity — launched in Kenya in December 2016.

Organisation: d.light design
Number of installations (households): not available (reported: 65 million lives impacted)
Areas of operation: Global
Employees: 400+
Pricing: A solar home system costs $25 deposit and $0.40 a day for a year. Total price paid: $171. After that, the system belongs to the customer. d.light then aims to upsell the consumer with a second system or one of its new white good products (a radio or TV to start, but soon, a fan or a fridge). d.light also offer pico-solar lights and solar kits at various prices. The newest light, the A1 is pitched as the most affordable light at around $7.

d.light also offer $5 solar lanterns as well as solar panels, converters, lights, cell phone chargers (and eventually other low-power appliances) through an instalment payment plan that can be financed through direct loans from the company or through micro-financing from local lenders.

Organisation: Off Grid:Electric
Number of installations (households): 100,000
Areas of operation: Rwanda, Tanzania
Employees: 800
Pricing: $6-9 installation fee, daily fee between $0.18-0.63, minimum payment of one day's use.

Off Grid:Electric guarantees service for the lifetime of the product and operates a 24/7 call centre to respond to customer needs. The package also includes a meter to keep track of energy usage, LED lights, a radio and a phone charger. It is a solar-as-a-service model so the customer does not own the system.

Organisation: Mobisol
Number of installations (households): 40,000
Areas of operation: Kenya, Rwanda, Tanzania
Employees: 400
Pricing: Basic package starts at $0.48 per day for 36 months for a solar home system – three LED light sets, mobile phone charger and a torch. For an additional $0.11 a day, customers can add a 15" TV. Total price paid: $526.

mobisol has developed a service offering fully adjusted to customers' needs: high-quality solar products, innovative IT solutions and remote monitoring, microfinance via mobile banking and comprehensive customer services. mobisol's products are made affordable by a rent-to-own instalment scheme offering micro-finance loans which are payable via Mobile Money.

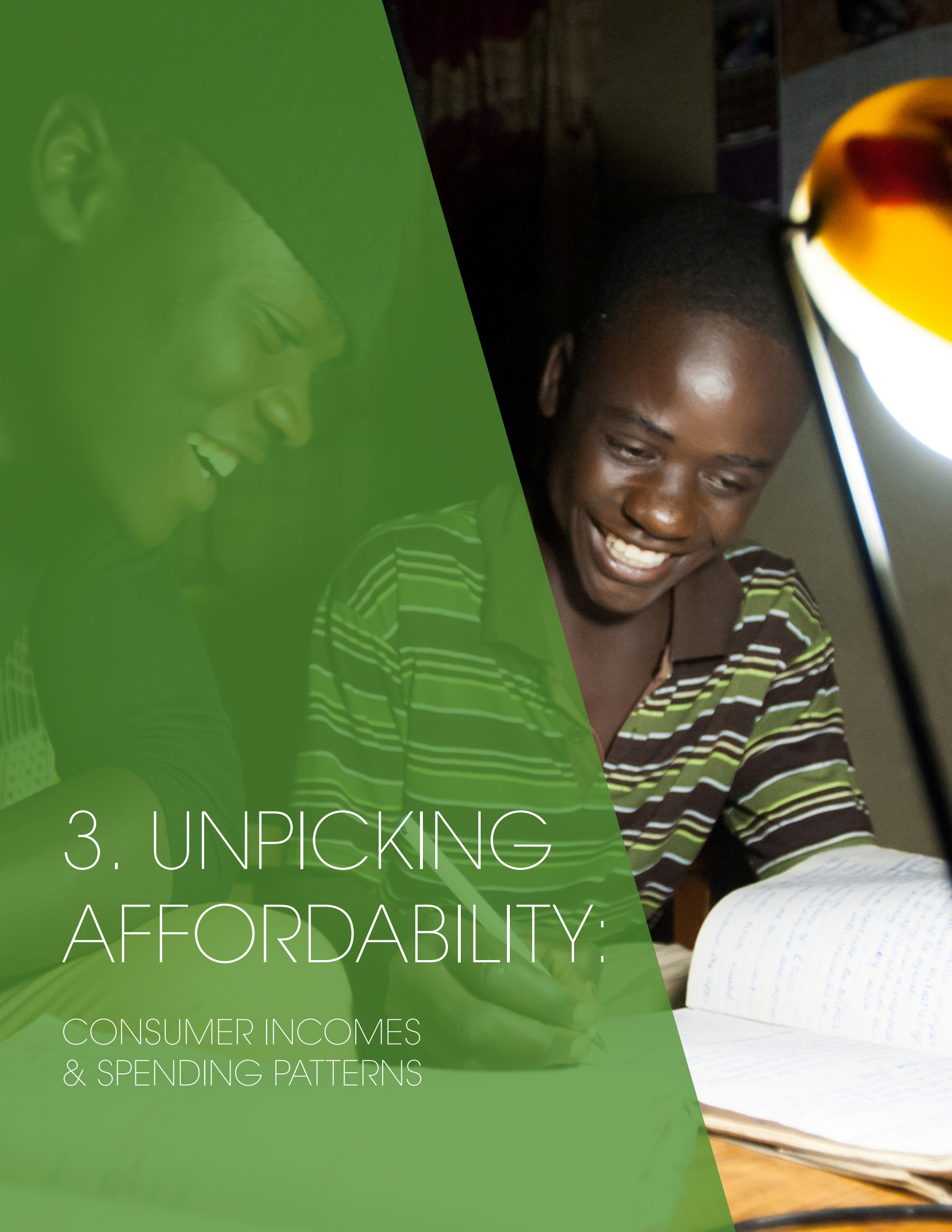
Organisation: BBOXX
Number of installations (households): 41,000
Areas of operation: Kenya, Rwanda, Uganda
Employees: 100
Pricing: Not shared. Credit available and loans can be paid off over 12-36 months.

BBOXX offers a wide range of products: from small solar home systems through to much larger systems which are big enough to power a business, health clinic, or institution. All BBOXX products are equipped with an extended warranty and comprehensive service plan.

Organisation: SolarNow
Number of installations (households): 6,100
Areas of operation: Kenya, Uganda
Employees: 408
Pricing: Payments available over 18 month loan period. Total price paid: average system $800, most system $500.

SolarNow sells solar systems to rural households and businesses in Uganda with an 18-month credit facility in order to make them affordable. It has 45 branches covering almost the entirety of Uganda, and is starting expansion in Kenya. So far the startup has sold 6,100 solar systems.

28. See References section for sources (multiple)



3. UNPICKING AFFORDABILITY:

CONSUMER INCOMES & SPENDING PATTERNS

Who are the poor?

Definition of poverty and the global poverty lines Firstly, we want to define poverty and the poverty lines used in this report. Despite the progress made in reducing poverty, the number of people living in extreme poverty globally remains high. The work to end extreme poverty is far from over, and a number of challenges remain. It is becoming even more difficult to reach those remaining in extreme poverty, who often live in fragile contexts and remote areas. Access to good schools, healthcare, electricity, safe water and other critical services remains elusive for many people, often determined by socioeconomic status, gender, ethnicity, and geography. Moreover, for those who have been able to move out of poverty, progress is often temporary: economic shocks, food insecurity and climate change threaten to rob them of their hard-won gains and force them back into poverty.[29]

The global poverty lines

The national poverty lines usually reflect the line below which a person's minimum nutritional, clothing, and shelter needs cannot be met in that country. Richer countries tend to have higher poverty lines, while poorer countries have lower poverty lines. To identify how many people in the world live in extreme poverty, a poverty line that measures poverty in all countries by the same standard is needed. We cannot add up the national poverty rates of each country, because this would mean using a different yardstick to identify who is poor in each and every country.[30]

In 1990, a group of independent researchers and the World Bank proposed to measure the world's poor using the standards of the poorest countries in the world. They examined national poverty lines from some of the poorest countries in the world, and converted the lines to a common currency by using purchasing power parity (PPP) exchange rates. The PPP exchange rates are constructed to ensure that the same quantity of goods and services are priced equivalently across countries. Once converted into a common currency, they found that in six of these very poor countries the value of the national poverty line was about $1 per day per person, and this formed the basis for the first dollar-a-day international poverty line.

After a new round and larger volume of internationally comparable prices were collected in 2005, the international poverty line was revised to $1.25 per person per day, and this became the revised international poverty line. Again in 2015, the World Bank updated to a new global poverty line of $1.90 in 2011 PPP. This is the extreme poverty rate. Alongside the $1.25 poverty line, there was a 'median' poverty line at $2.50. The World Bank also updated this line to $3.10. The Acumen Lean Data team and many others around the world align to the World Bank poverty lines as this is the most credible and robust calculation available.[31]

Are the poor consuming off-grid energy?

With little direct data on the question of affordability one way to begin to unpick the question is to understand who purchases off-grid energy, and how deep the penetration is into the markets in which it is available. The premise here being that if the poorest, most rural people are purchasing products such as solar affordability must be relatively manageable to most consumers. If, on the other hand, we see only wealthier, urban consumers adopting modern off-grid energy solutions there may be a significant challenge.

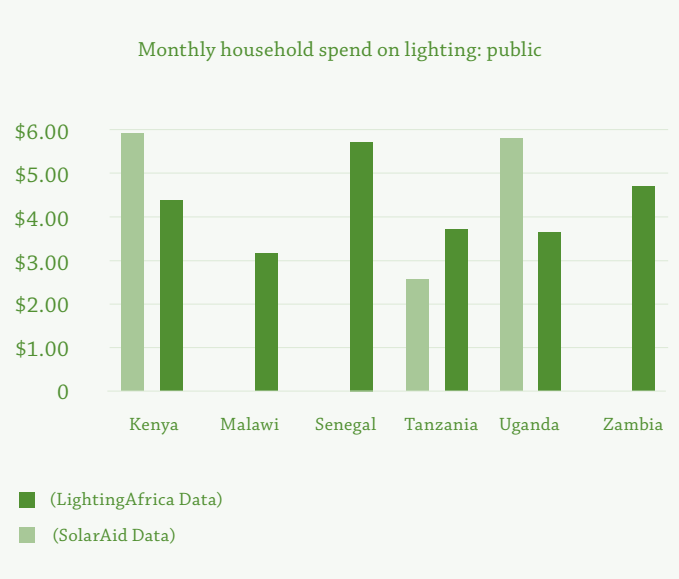
SunnyMoney, the social enterprise founded by SolarAid, estimate that 82% of their customers buying the simplest solar-powered lights costing around $10 live below the $3.10 per person per day poverty 18 line: 62% in Zambia, 73% in Tanzania, 85% in Kenya, 85% in Uganda, 99% in Malawi.[32] Acumen's data, collected using the Progress out of Poverty Index,[33] has shown similarly encouraging ability of companies to reach poorer consumers. Using weighting from sales, 36% of the customer base of five SHS and mini-grid companies across four East African companies lives below the poverty line at $3.10 per person per day.[34] 82% of customers of a solar mini-grid PAYG service in Tanzania live below the $3.10 per person per day poverty line, compared to 29% for an Indian hybrid mini-grid service company.

29. World Bank (2016). Overview of poverty.
30. World Bank (2015). FAQs: Global Poverty Line Update.
31. World Bank (2015). FAQs: Global Poverty Line Update.
32. SolarAid (2012-2015). Results from pico-solar customer and market research in Kenya, Tanzania, Senegal, Malawi, Zambia, Uganda.
33. More can be found on the Progress out of Poverty Index (PPI) here.
34. Kenya, Rwanda, Tanzania, Uganda.

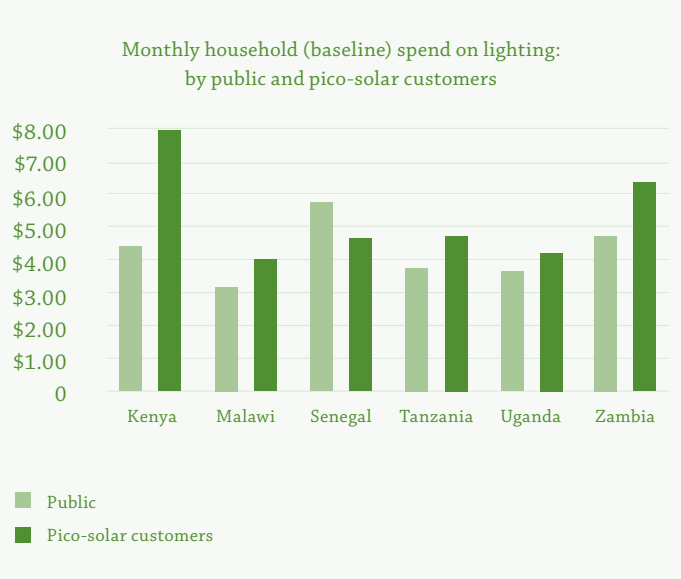
How much are household's spending?

SolarAid's market research with rural consumers across Kenya, Uganda, Tanzania, Malawi, Zambia, and Senegal shows that families spend an average of ~$4 each month on lighting alone. Similarly, Lighting Africa (2011) surveys conducted in Ethiopia, Kenya and Zambia found that a typical off-grid household in these countries will spend on average $4.75 monthly on energy costs which increases to $6.25 when mobile phone charging costs are included. SolarAid data also shows that customers of solar lights were spending more on lighting prior to purchasing than the general population. This could reflect the higher income status of customers,[35] but also a greater desire to reduce spending on lighting in the longer-term which motivated the purchase. Notably, there are variances within countries, especially between rural and urban populations. Kerosene prices are an estimated 46% higher in rural areas of Africa compared to urban areas.[36] The charts below map this out to show that we are starting to get a strong sense of the range of spending on energy for off-grid families in Africa.

A later study by Lighting Africa (2012) in Senegal, Mali, Ghana, Tanzania and Kenya estimated household spend on energy between $5.83-9.17 monthly, which was equal to 2-5% of annual household income. 90% of these households were using kerosene lanterns and/or battery-powered torches for lighting. A study by ETH currently managed by Acumen on the economic impact of solar lighting in Kenya found similar levels of spend on energy.[37] Data from 1,400 households in rural areas of western Kenya, showed an average household would spend 3-5% of overall monthly cash expenditure on energy: lighting and phone charging. Kerosene accounts for 95% of average monthly spend on lighting for these households



Source: Lighting Africa and SolarAid



Source: SolarAid

35 A SolarAid (2015) study of 3,500 people in Kenya, Tanzania, and Zambia found that its pico-solar light customers had income levels 11%, 47%, and 208% above the local average, respectively.

36 Tracy and Jacobson (2012). The true cost of kerosene in rural Africa

37 Rom, Gunther, and Harrison (2017). The Economic Impact of Solar Lighting: Results from a randomised field experiment in rural Kenya

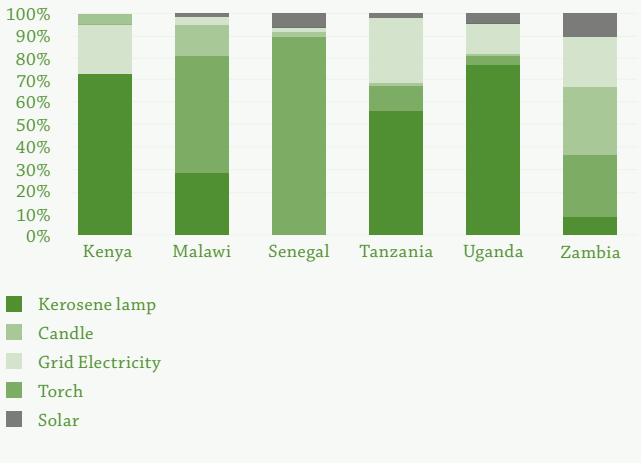
> We were spending a lot of money on buying paraffin [kerosene] and charging our phones and we wanted to reduce that expenditure.
>
> Uganda

What do people use prior to solar?

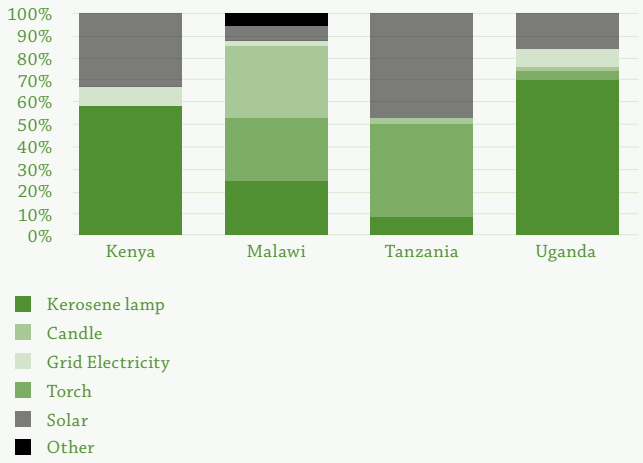
SolarAid investigated primary sources of lighting prior to purchasing a pico-solar light. Adoption of solar is likely shaped by baseline methods of lighting in terms of familiarity with modern technology, and also desire to move away from flame-based, polluting sources such as kerosene lamps and candles. While there are variances across and within countries in Africa - often due to subsidies (for kerosene), import tariffs (for batteries or solar lights), and transportation - these studies paint a picture of the types and amounts spent by off-grid families to access lighting and phone charging prior to solar.

The first chart shows that in East Africa kerosene is the main source of lighting prior to solar light purchase, whereas in Southern and West Africa torches were the main source. The second chart shows data from Acumen on energy sources prior to purchase of higher level systems and the results show strong signs of an energy ladder, and a confidence and familiarity with solar products shaping future purchase. This tells us that for customers purchasing larger solar systems, there is a higher chance they would've previously experienced solar energy.

Pico-solar light customers: Main source of lighting for households prior to purchase



SHS/mini-grid customers: Main source of lighting for households prior to purchase



> [The solar light] is expensive. I do not have the money.
>
> Kenya

Discerning customers are sensitive to price

As well as indications on general income levels and consumption patterns, recent research undertaken in collaboration with Acumen has unveiled some insights about the price elasticity of demand for solar lights, albeit for a single product type in a single geography.[38] By offering a voucher with different prices to 600 households, the study concluded that the demand for solar lights is fairly price elastic. At market price of $9, discounted price of $7, heavily subsidised price of $4 and free, uptake of solar lamps was 29%, 37%, 69%, 100% respectively. This shows that small price changes lead to larger responses in uptake. Additionally the study found that usage patterns were unaffected by price paid.[39]

The same research also discovered, not surprisingly, that poorer households spend a relatively larger share of their total expenditure on energy but as families become wealthier, energy expenditure falls as a proportion of total expenditure. The poorest quintile of Kenyan consumers spent around 10% of their total expenditure in energy compared to the average across all households of around 5%. This is building a picture of an eager, yet price sensitive consumer and also interestingly that targeting deep into the base of the pyramid may be a promising marketing strategy, certainly as displayed by the charts above which show evidence of an energy ladder to some extent.

The findings of price savvy consumers is consistent with previous discoveries made by SolarAid. General public surveys in Kenya and Tanzania undertaken in 2015 found that price was the main reason given by households for not purchasing a solar light. Perhaps this explains the success of sales of lower quality generic solar lights. Some organisations have also been naturally responding to these market signals by introducing lower-cost pico-solar lights, including d.light, Greenlight Planet and Nokero. SolarAid launched its 'ultra-affordable' $5 pico-solar light in 2016 moving closer to the cost of generic products. Quality of products is discussed in a later section.

38 Rom, Gunther, and Harrison (2017). The Economic Impact of Solar Lighting: Results from a randomised field experiment in rural Kenya.

39 This last finding can be used to dispel any notion that receiving solar energy products free might undermine the value of the product – a criticism that has been applied to the free give away of some cookstoves.

4. THE APPEAL OF FINANCING

> It is affordable to many people due to various bundles that a customer can buy according to the level of income.
>
> Tanzania

> I am a person of low income I could not have afforded to own such a thing if it were not for the credit method of payment.
>
> Kenya

Along with efforts to drive down prices, considerable attention has been paid to financing as a way of making access to more powerful energy products or services more affordable. Financing helps to lower, or eliminate upfront costs, and spread payment over more manageable periods of time for families with little give in their disposable incomes. But it still may involve switching of expenditure and the rise in overall costs to include financing means that it may have negative impacts on those at the cusp of affordability.

Rent-to-own and perpetual leasing

One of the most established forms of financing is pay-as-you-go (PAYG). PAYG is generally used as a generic term in the off-grid energy sector but encompasses two distinct financing models: rent-to-own - where regular payments lead to eventual ownership - and perpetual leasing, where the consumer pays for energy consumption but never owns the underlying asset. Examples of companies adopting a rent-to-own model include Fenix, mobisol, M-KOPA, d.light, SolarNow, and Simpa. Examples of companies using leasing models are Off-Grid:Electric, Persistent Energy, BBOXX, Devergy, and Econet Solar.

Findings from Bangladesh showed clear preferences for financing. When given an option between financing and upfront cash payments more than 90% of customers chose the former.[40] Similarly Acumen's own data suggested that for one SHS company 53% of customers said that the driving reason they selected the company was the mode of payment on offer only 3% said price was the main reason (other factors included no other options available, and quality). And although most energy products offered on credit are solar kits or home systems - due to transaction costs of arranging debt - SolarAid piloted PAYG for pico-solar lights in Kenya in 2015. They found purchase rates for entry-level solar lights increased from 10-15% of parents at the schools they distribute through to 20-50%.[41]

Paying in instalments reduces risk for customers investing in new technology or brand. They have time to test the efficacy and quality of the product or service before handing over full payment. One study saw an increase in trust in the quality of products and companies from their study of SunnyMoney's and M-KOPA's PAYG services.[42] During the SunnyMoney PAYG trial in Kenya the study observed that of the 80% of households who completed their repayments to own the solar light, 15% made a full repayment in the initial 30 days following the deposit despite the original term being for six months. Data from focus group discussions and surveys suggested that this was due to greater trust in the product after a trial period afforded by the payment terms. This implies a virtuous cycle of greater affordability and trust through such financing models and exposure.

40 Brossmann (2013). Off-grid Rural Electrification and Fighting Poverty. A Comparative Impact Assessment of Solar Home Systems and Small Solar Home Systems in Rural Bangladesh

41 And in a later trial in Malawi in 2016, repayment rates were an impressive 99%.

42 Alstone, Gershenson, Turman-Bryant, Kammen, and Jacobson (2015). Off-Grid Power and Connectivity: Pay-as-you-go financing and digital supply chains for pico-solar

> If you see someone giving you a lamp to pay slowly, that means they have confidence with their product.
>
> Kenya

> I am concerned about using [mobile money] to make the payments. I don't understand how it works.
>
> Haiti

Mobile money: opportunity and limitation?

There has been considerable excitement about the potential for mobile money to unlock access to solar home systems by making credit simpler and lower risk. M-KOPAs rise to the front of the SHS pack is testament to the seeming appeal of this form of financing. However this can also be limiting in terms of adoption. A 2016 survey by Lighting Global found that 60% of PAYG companies use mobile payments to collect revenue.[43] This may be an excellent strategy for countries such as Kenya, where penetration rates for mobile money are high - GSMA report that 70% of the population were using mobile money regularly as of 2013.[44] However, other countries do not enjoy such high mobile-money penetration rates due largely to more restrictive banking regulations. Comfort levels with using mobile money can also be a barrier which are sometimes linked to literacy rates and age.

While SolarAid's first PAYG trial in Kenya used mobile money for households to make payments, their later trials in Kenya and then Malawi switched to cash payments due to the limitation of mobile network coverage and mobile money penetration. A flexibility for companies to switch to cash payments in areas with low mobile network coverage may resolve this. However, this may increase costs for companies who ultimately use digital payments to reduce transaction costs for their portfolio.

Causality may also run the other way with suggestions that the adoption of PAYG solar lighting which use mobile money as a payment system actually encourages households to become a new user of mobile money services.[45] As many as 30-50% of PAYG customers outside of Kenya were new to mobile money and opened a mobile account in order to purchase a digitally-financed energy solution. This affect may not be universal. In another African country Acumen's own data showed a more modest increase from 77% of customers without mobile money prior to connection which increased to just 82% three months later.

43 GOGLA (2016). Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data January

44 GSMA (2016). The Mobile Economy

45 Winieki and Kumar (2014). Access to energy via digital finance

> Whenever I pay, per day for example; if I want to pay 40 KSH they deduct 55 KSH. Is it [the solar] company that take the money or MPESA because am spending a lot of money?
>
> Kenya

However, mobile money payments are not free and have been shown to impact the affordability of PAYG products as a result of fees levied on transactions by network operators which can add up to as much of a fifth of the overall gross costs incurred by consumers.[46] It's possible that the net additional costs are lower if the efficiencies of mobile money allowed the provider to lower its pricing. Additionally, some mobile money operators may be working to reduce these fees, for example, M-Pesa has removed fees on small transactions through its M-Pesa Kadogo Initiative.[47]

In addition, while remote monitoring and the ability to switch off systems when payments are not made acts as an incentive for households to pay their instalments to get service, it has the potential to leave families in worse off positions if they struggle to make a payment.

46 Alstone, Gershenson, Turman-Bryant, Kammen, and Jacobson (2015). Off-Grid Power and Connectivity: Pay-as-you-go financing and digital supply chains for pico-solar

47 Kachwanya (2016). M-Pesa Kadogo – Safaricom drops charges for sending funds below KSh.100.

> [I did not buy because]
> I did not have money to pay for the deposit.
>
> Kenya

Wider challenges: down payments, credit-checks, repayment issues and financial literacy

Although financing provides a reduction of price in the short term, as mentioned, a one-off up-front deposit payment is common for many PAYG offerings. This can act as a filter function to eliminate customers who are more likely to default on future payments. Deposits are typically 10-30% of the fully financed cost of the solar product.[48] IRENA suggest that despite the apparent consumer preference for credit arrangements these down payments can still be a barrier to affordability of SHSs.[49] For a basic system, $30 is typically required as the initial payment. Considering Lighting Africa's estimate of rural African household's monthly spend on energy between $5.80 and $9.20, this initial cost might still be a constraint to affordability. Work commissioned by Lighting Global drew a similar conclusion when analysing M-KOPA's initial payment of ~ $30 - equivalent to a month's salary of many off-grid customers - for the M-KOPA III system.[50]

In addition to upfront down-payments another factor that may limit adoption for the poor may be credit approval processes. The majority of credit checks struggle to accommodate or predict the impacts of seasonal or unexpected fluctuations in income.[51] This may mean that agricultural workers with seasonal income, and little credit history may struggle to access financing. However for those that are able to access credit, this may be an exciting pathway toward financial inclusion. Acumen's data from its own portfolio has found that accessing energy through financing is often the first time many customers have received credit. This was the case for as many as 83% of customers for one East African SHS company.

On the other side of the coin from credit-checks, is the potential for repayment issues, from 8% for customers of one company in East Africa to 28% for another in India. A separate study in Rwanda even found that as many as 52% of consumers reported struggling with the regular payments.[52] To address this companies could consider offering uneven instalment payments so families could pay more at times of higher income. Other options include payment holidays and rescheduling of term of loan to make larger systems on credit more affordable to lower income families with less reliable incomes.

One thing that most PAYG companies have in common is that they require their customers to sign contracts or agreements when registering for credit. There is evidence that customers are unclear of what they are signing up for and this leads to subsequent defaults. Indeed, according to data Acumen collected from our own portfolio companies 27% of customers felt that the agent did not explain the contract to them adequately during sign-up, and 13% said that parts of the payment plan were unclear. Interestingly, of these, 23% said it was the mobile money link that was unclear to them, with payment timing, amount, and length of contract also being areas of confusion. For the study on Rwanda mentioned above, 44% reported 'technical problems' which were found to mostly be a lack of understanding with the payment process. Delayed or defaulted payments not only affect companies' accounts, but may also affect a customer's ability to access credit in future.

48 Winieki and Kumar (2014). Access to energy via digital finance

49 IRENA (2016). Solar PV in Africa: Costs and Markets

50 Alstone, Gershenson, Turman-Bryant, Kammen, and Jacobson (2015). Off-Grid Power and Connectivity: Pay-as-you-go financing and digital supply chains for pico-solar

51 Alstone, Gershenson, and Kammen (2015). Decentralized energy systems for clean electricity access.

52 Collings and Munyehirwe (2016). Pay-As-You-Go Solar PV in Rwanda: evidence of benefits to users and issues of affordability

5. BEYOND AFFORDABILITY:

AWARENESS, ADVANTAGE & ACCESS

> I have never seen [the solar product] before. If I knew where to find them, I would consider buying.
>
> Zambia

> I had a friend who bought earlier and he is the one who told me about [company] products and the mode of payment.
>
> Uganda

While this study was commissioned to look at affordability, the price of a product or the availability of financing is only one influence in the decision to buy. In this section we look briefly at other factors that affect adoption. To do so we use the framework developed by Acumen and Bain & Company in our 2014 report on the drivers of adoption of agricultural technology, Growing Prosperity.[53] This report introduced the four As framework for adoption: Awareness, Advantage, Affordability, and Access.

Awareness: "Do I know about the product or service, and what have I heard about it?"

Our first "A", Awareness, represents both the knowledge of a product or service itself and also awareness of how to use it most effectively. An Acumen Lean Data study with unconverted leads of a SHS company found that the most common reason for a decision not to purchase was a lack of information on the product (affordability came in second). An earlier SolarAid public market study saw that awareness of pico-solar lights varied greatly throughout different markets with 96% of respondents knowing about solar lights in Kenya, 88% in Tanzania, 47% in Zambia, 38% in Malawi, and just 20% in Senegal.

Though the market and awareness has surely progressed since this time this shows that even relatively recently awareness has been surprisingly low.

This highlights the importance of company marketing and consumer awareness campaigns Forthcoming baseline results from the Schatz Energy Research Center (SERC)[54] on the energy ladder in Uganda confirmed that direct marketing from companies influenced rural household's decision to purchase a solar product.[55] 86% of customers mentioned getting information from solar organisations directly from sources such as sales calls, demonstration campaigns, and radio advertising. The study suggested that effective demonstration helps improve solar technology literacy; awareness of and confidence with this as an energy source, and it assumed consumers are then more likely to adopt solar energy technology as their ability to evaluate relative benefit was higher. A new model, tested by SolarAid in Senegal, saw that offering access to solar products in a try-before-you-buy approach doubled subsequent purchase rates.[56] Companies can also leverage their institutional partners. For one company in the Acumen portfolio our data found that 70% of sales originated through their local microfinance institution (MFI) partner.

Social networks play a critical role in driving awareness. The SERC study suggested that the marketing activities of the solar energy companies in Uganda were seen to increase information predominantly through social networks. Acumen's own Lean Data work shows that differing business models and distribution channels greatly affect how potential customers hear about off-grid energy services. One SHS company in East Africa saw over 40% of sales come through recommendations from friends or neighbours. Women may also play an important role as they are part of social networks that differ from those of men and can have access to hard-to-reach households.[57] This is an argument for including women in the supply chain as well as identifying ways to engage them as customers and influencers, such as through referral or ambassador programmes.

53 Adams, Dichter, Mitchell, and Tam (2014). Growing Prosperity: Developing Repeatable Models to Scale the Adoption of Agricultural Innovations

54 Jacobsen and Goyal (2017). Preliminary findings: the Energy Ladder. Co-managed by Kat Harrison at Acumen and the United Nations Capital Development Fund (UNCDF). Not yet published.

55 The SERC study collects data from four solar energy companies in Uganda at different levels of the energy ladder: SunnyMoney, Greenlight Planet, Fenix, SolarNow.

56 More information on the Light Library model can be found here.

57 ENERGIA (2017). The case for a gender perspective on energy access

> Because now I can do other activities that I couldn't do during night and my house is full of light; actually my life has improved.
>
> Tanzania

> [I connected to solar to avoid] disturbance because sometimes lamps went out of kerosene but when you go to the shop it is closed so we have to be in darkness the whole night.
>
> Tanzania

Advantage: "How much more benefit will I gain from this product or service relative to what I'm currently using?"

Perceived advantages of any product come in a multitude of forms from quality and design, reduced risk, to prestige relative to peers. For access to energy, and solar in particular, the list is long and varied and we could easily dedicate a whole report to these. Here we try to summarise some key themes and give a sense of the relative importance of them. We only consider immediate advantages to consumers, and therefore almost entirely ignore the advantages relating to the environment.[58]

At Lean Data we talk to a lot of customers about their product and service satisfaction. As a general rule customers of solar products seem happy with their purchases. In our research we see relatively high levels of customer satisfaction, including when compared to purchases across other sectors. Customers identify having access to more and brighter light, improved energy reliability, and reduced expenditure (especially for adoption of pico-lights where savings from switching from fuels like kerosene are greatest) as the most significant advantages but also improvements in feeling more secure/safe, and feeling healthier, cleaner, and happier in one's home. While lower tiers of access do not meet all energy needs, there is high relative benefit for customers progressing here. The relative benefit of electrifying a poor household is higher than that of electrifying a higher-income household.

Customers tend to report increases in the range of 1-2 hours per night following purchase of solar energy products. SolarAid (2012-15) research found that after purchasing a pico-solar light, households increased the amount of time that they had light in their home from 4 hour per night before to 5 afterwards.

With respect to expenditure savings, one of Lighting Africa's earliest reports from 2010 suggested that replacing kerosene lamps with solar lights could offer returns on investment of 15-45 times the cost of the solar light. SolarAid research from 2012-2015 found that families across Africa with a solar light save over $60 a year, recouping the cost of the solar light within an average of just 10 weeks and subsequently spending just 2% of their household income on lighting. In aggregate terms, the Africa Progress Panel reported that halving the cost of inefficient lighting sources would save $50 billion a year for people living below $2.50 per day.[59] It is estimated that these monetary savings would be sufficient to reduce poverty by as much as 16-26 million people.

58 Acumen and SolarAid research has seen that consumers rarely list environmental factors as a driver for purchase across Africa.

59 Africa Progress Panel (2015). Power, People, Planet: Seizing Africa's energy and climate opportunities

> Before I purchased the solar I was using 50 KSH per day but now I can use that money to pay for the solar and save what I was using on batteries and phone charging.
>
> Kenya

However, it's not always the case that customers make savings. Families can spend more for energy after purchasing a more powerful SHS during the repayment period. A study commissioned by d.light on their PAYG solar home systems in Uganda found that household expenditure on energy increased when making repayments toward the cost of one of their more expensive $240 units.[60] A similar study on Azuri's PAYG solar home systems in Rwanda also found that households were paying marginally more for energy after the purchase of their SHS, from $4 to $4.70 per month.[61] Results from Acumen's Lean Data work with their energy portfolio saw differing changes in spending. For one perpetual lease model in East Africa there was little change in spending on lighting and phone charging for customers; spending was simply diverted from prior methods to the solar provision. Two SHS companies' customers in East Africa saw increases in energy spending from $9.50 a month to $15.15 during the repayment period for one, and a doubling for another customer base ($5.90 per month to $11.80).

Beyond spending, replacing kerosene lanterns with cleaner, safer alternatives like solar products help reduce household air pollution. The fine particulates emitted by kerosene lanterns exceed WHO guidelines and contribute to respiratory illness. Epidemiological research on the health effects of kerosene lighting is currently limited and inconclusive. However, a research study at UC Berkeley which will be released in the coming months shows early results suggesting that children may be more adversely affected by usage of kerosene.[62] Using flame-based lighting can also lead to accidents, burns and fires.[63] 19% of SolarAid customers interviewed in Uganda between 2013-15 had experienced fires, burns and/or poisoning from kerosene.

60 IDinsight (2015). d.light Solar Home System Impact Evaluation

61 Collings and Munyehirwe (2016). Pay-As-You-Go Solar PV in Rwanda: evidence of benefits to users and issues of affordability

62 Lam, Muhwezi, Isabirye, Harrison, Ruiz-Mercado, Amukoye, Mokaya, Wambua, Bailey, and Bates (2017). Exposure reductions associated with introduction of solar lamps to kerosene lamp-using households in Busia County, Kenya.

63 There have even been incidences of poisoning through consumption, children mistakenly drinking kerosene stored in used soda bottles.

> Smoke [from kerosene] has reduced, before children used to cough all the time because of that.
>
> Kenya

> I have a son in class 7, his performance has shocked me; he was performing so poorly but since I got the solar he is so motivated. Last term he was position 3 and he has always been in last position. I was so happy and I feel good that my children are doing well.
>
> Kenya

> I was tired of buying kerosene and making trips to the market.
>
> Kenya

There has also been significant attention to the impact of solar lighting on children's education. SolarAid found that school children in Kenya, Malawi, Tanzania and Zambia rated limited lighting as their main barrier to doing homework. Baseline results from a Stanford University study in Zambia64 showed that 10% of the time students did not complete homework it was because it was too dark, and 8% of the time students missed school because they hadn't completed homework. SolarAid research reports that children increased their study hours by an hour per night after accessing a pico-solar light. Acumen's data supports this pattern seeing increases of evening study hours for children on average at 1.0, 0.8, and 0.4 across three different companies. These differences may reflect business models; SolarAid work through schools to promote pico-solar lights for child study. It may also reflect the type of solar product. A SHS offers fixed ambient light with no portability, a pico-solar light is often more of a directed task light; this may change behaviour and usage, particularly when reflecting on who in the household has access to the lighting. Even so, the d.light study above found no increase in productive hours, including study, following purchase of a SHS.

Other advantages may include things like time savings; Acumen's data suggests an average of 3.5 hours saved per month from avoiding going to market to purchase kerosene or candles, and visiting kiosks to charge phones. Perceptions of safety is important with 96% of solar home system customers of an East African company reporting to Acumen that safety in their home had got better as a result of having the SHS, and 61% of customers of a different company. Social status has been explored; in Bangladesh, 82% of home system users agreed that their system had increased their social status. Lastly, social activities or leisure time may be affected; Acumen's data indicates that families in Uganda and Kenya with a SHS report spending an extra hour on social time with friends and family.

64 Managed by Kat Harrison at Acumen.

> I charge for people their phones and the money they pay I redirect to making payments for the SHS.
>
> Kenya

> When customers visit, the shop is visible. During summers, the fan can be used and customers stay for some time and purchase the things.
>
> India

Energy access and income generation

Acumen's research suggests that income generation may play a relatively smaller role in the motivation to access modern energy. For those who do use it for this, it is highly significant. Acumen's data suggests that for 10% of SHS customers, 13% of mini-grid customers, and 3% of SHS customers of companies across East Africa their energy service was purchased for use in their small business – normally shops, restaurants or bars. In addition, 6% of household-use customers of one company used their home system for income-generation – normally phone charging for neighbours.

Another earlier study from 2009 found no increased income-generating activities were reported in households who purchased solar home systems in Uganda, but that solar light led to longer hours of operation and higher profits in existing microenterprises.[65] It also found that micro-enterprises in Uganda with solar home systems experienced higher profits due to their ability to attract new clients with 12% more businesses reporting growth in sales than those without home systems. This is consistent with customer interviews by Acumen that suggest that where a home system is used for income-generating purposes, it can have significant impact on income levels. 91% of business-use customers had seen increases in their income of nearly 60% on average. Not only this, but 86% of these businesses said they 'absolutely' relied on the home system for their business. Nearly 85% of business-use customers of an Indian mini-grid company said their business had evolved as a result of their connection saying that they were able to stay open or work for longer, and nearly 20% mentioned that customers were more comfortable in their shop/restaurant/bar. It is, therefore, not surprising that increasingly pay-as-you-go energy companies are either focusing on small business for sales and/or encouraging the use of their energy services or products for income generation.

65 Harsdorff and Bamanyaki (2009). Impact Assessment of the Solar Electrification of Micro Enterprises, Households and the Development of the Rural Solar Market

> [company] is the only service found in our village; there is no alternative for energy access.
>
> Tanzania

Access: "Can I get it easily when I need it?"

Challenges in access are mixed but improving rapidly. In Kenya, SolarAid found that knowledge of where to buy a solar light has increased rapidly over the past two years, from 31% to 75%. Consumers. The estimated distance required to travel to purchase a solar product fell from 63 to 4km. By contrast in Tanzania, consumer awareness of where to purchase increased from 15% to 49% over two years.66

Distributors complain that their inability to maintain sufficient stocks affects availability to customers and sales agents report a lack of agent-financing to maintain and manage their own businesses. Interviews with sales agents in Kenya suggested that their inability to purchase sufficient inventory is limiting their potential to serve households with solar lights.67 Managing inventories is an important issue and SolarAid also discovered that consumers preferred to buy a product and leave with it the same day, and were nervous if they had to make an upfront payment for something that would be delivered later.

In general, the solar lamp market has suffered from an influx of substandard products which has reduced consumer trust in the product, potentially hampering the adoption of quality goods. Of total global sales of 44 million quality-assured solar lights, more than half of these (24 million) have been of generic products. This is likely a function of lower price, and potentially wider availability. These generic or poor quality products are often sold in markets by traders rather than branded shops so there is often no opportunity to seek after-sales support. What's more, if the product breaks earlier than expected, the initial outlay of cost may not have been recovered through reducing spending on lighting alternative. In the short term, then, families may be worse off economically. The World Bank and IFC's joint initiative, Lighting Global has created a quality assurance programme to assess durability of solar energy products being sold in developing markets, to provide some protection for customers from poor quality products. Acumen's own data underscores this problem, with non-customers of one SHS company in East Africa stating that concerns over quality was the main reason for potential customers choosing not to sign up for a home system as yet.

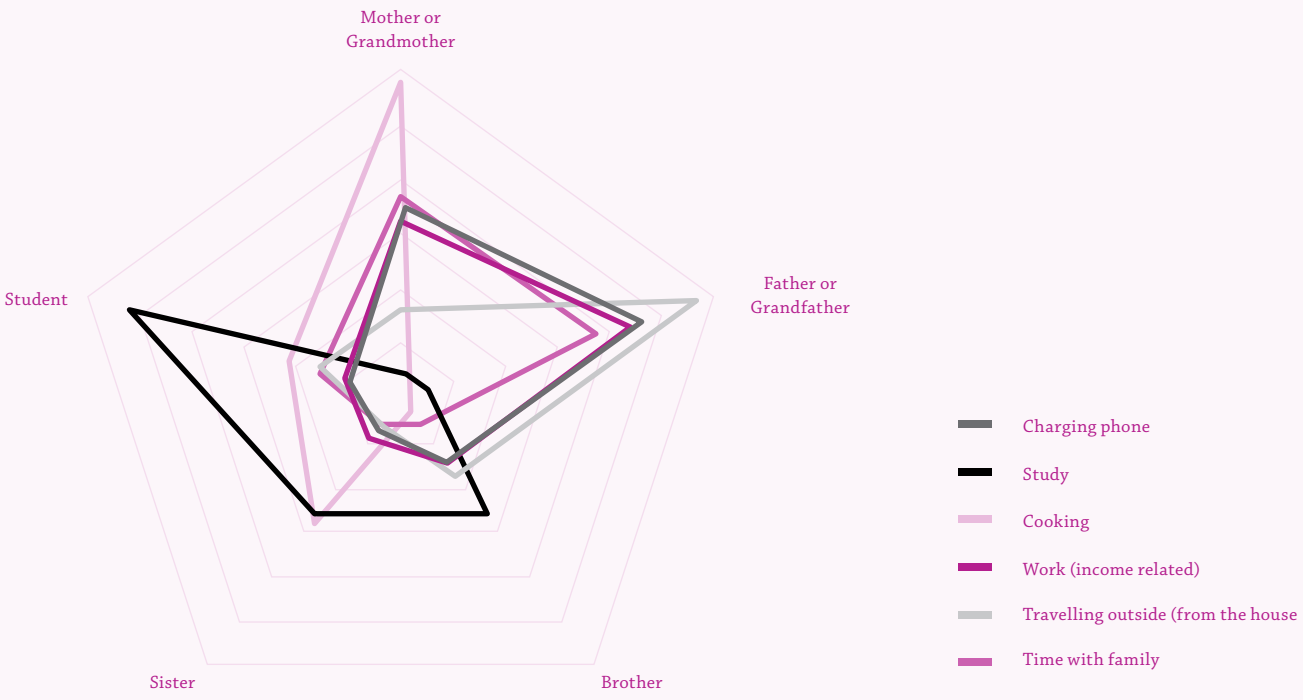
66 SolarAid (2015). Baseline and follow up market research. 3,500 respondents over 45 markets.

67 Alstone, Gershenson, Turman-Bryant, Kammen, and Jacobson (2015). Off-Grid Power and Connectivity: Pay-as-you-go financing and digital supply chains for pico-solar

A note on gender dynamics

Due to limited evidence of impact and affordability as a whole in the energy access sector in Africa, there is little that has specifically focused on gender dynamics and differences in affordability. We have mentioned specific opportunities for engaging women, and the effects of this, throughout the report, but we add some additional insight here. ENERGIA (2017) found that the purposes for using energy and levels of access to energy differed between men and women.68 SolarAid (2015) explored this link further in research conducted in Kenya, Malawi, Tanzania, and Zambia to understand breakdown in responsibilities for certain activities in the house and whether interaction with energy differed by gender. The research found that women were most likely to use light for cooking but that male members of the household were most likely to use light for income-generation related activities and for travel outside of the home, as well as for charging phones.

Activities that lighting is used for, by family member



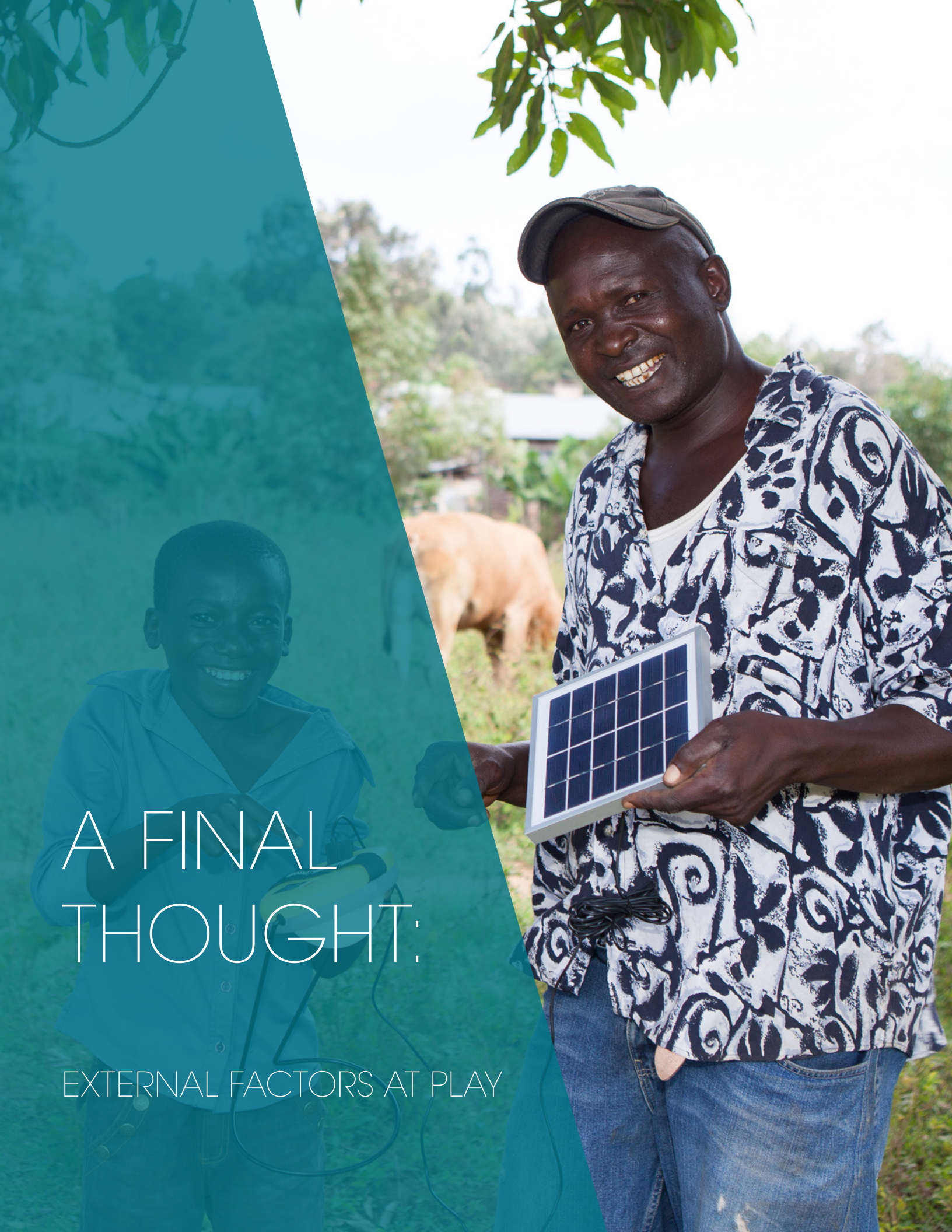
Source: SolarAid

> Where I stay there is no firewood so I normally spend a lot of time going to look for firewood. But since I got [improved cookstove] I no longer go to collect firewood.
>
> Kenya

Our recent Lean Data project has asked customers, who in the household made the decision to purchase the energy service? Our data has tended to show that most purchases were joint male/female decision, followed by male only then female only. In only one case, a mini grid company, did the decision appear to be overwhelmingly male-led with 90% of the customers reporting that it was the male of the household who made the decision to connect. But equally for one PAYG SHS company in East Africa, 90% of the registered main users were women; this company sold predominantly through MFIs and women's groups. When broadening out the conversation to encompass cooking, there are even deeper impacts on women that access to improved cookstoves can have; saving time cooking as well as purchasing or gathering fuel, and improving health from reducing indoor air pollution or exposure to smoke. Acumen data for one East Africa cookstove company saw families reporting to save one hour each month, on average, from not having to purchase or collect fuel for cooking.69 There is also an opportunity to include women in the supply chain; the voice of women can contribute to more balanced and diverse decisions, and ENERGIA asserts that opening up the sector to women in non-traditional jobs increases their chances of income generation and empowerment.

68 ENERGIA (2017). The case for a gender perspective on energy access

69 86% of the households previously bought fuel. For those who collected it there are likely to be higher time savings as a result of more efficient cookstove use.



A FINAL THOUGHT:

EXTERNAL FACTORS AT PLAY

In this penultimate section we take a brief look at some of the factors external to the firms in the market that influence adoption of energy. Many of these topics could warrant a whole report to themselves so we only provide cursory comments on a handful of factors.

Policy and tax environment

It should be little surprise that solar markets have attracted most investment and developed most rapidly in countries where there are attractive business environments. ClimateScope, an interactive research resource which tracks the conditions for clean and off-grid energy in 58 countries, shows that the same countries which have the most PAYG providers also have the highest ranking business-enabling environments. These same countries are also highly ranked for financing and inward investment.

Taxation plays an important role. Import and excise duties, value-added tax, and surcharges all affect the end price consumers pay. One study suggests that these taxes could increase the price of a solar light by 5-30%.70 However, progress is being made. The Ethiopian government has waived duties on all off-grid lighting products that meet or exceed Lighting Global's quality assurance targets. The Kenyan government has made all imported LED lighting equipment and solar components exempt from taxation and in Uganda, the government is implementing a 45% subsidy on solar equipment.

While these are positive individual examples, the East African Community, the regional intergovernmental organisation71, re-interpreted the tax rules on solar lights in August 2016 which led to an overnight introduction of a 24% tax (18% VAT and 6% duty) on the import of solar lights. GOGLA and its member organisations are currently challenging this reinterpretation, yet, it shows the volatility of policy decisions.

Subsidies and giveaways

In some countries rather than renewables being promoted it is existing fossil fuels that are subsidised. Such subsidies suppress demand for modern lighting devices due to relative affordability. Turman-Bryant (2015) says that, while the removal of kerosene subsidies would provide more reason for a household to switch to solar, there is also the potential for revenue to be created by governments because the money not spent on kerosene could be spent on other taxable goods.72

To counter this and promote renewables organisations such as the World Bank have previously subsidised unit sales. There are also instances of foundations and African governments providing solar products for free. Typically, this is negatively received by the private sector due to fears of market distortion. However, there may always be a case for subsidising the most marginalised communities (Justas energy subsidies are provided to vulnerable groups in the UK). Moreover if greater evidence of an energy ladder is established, provision of free entry-level solar energy products to the poorest may act as an initial spur to get on, and start climbing the ladder.

Donor agency initiatives in energy access

Following the establishment of SDG7, there is new focuses by international groups, foundations and NGOs in the energy sector. There have been a range of high profile initiatives including Power Africa which looks to build renewable energy projects that will connect to the national grid. In 2015, the UK's Department for International Development announced their Energy Africa campaign supporting initiatives to get solar household systems to off-grid households. The UN's Sustainable Energy for All is a global platform to empower leaders to broker partnerships and unlock finance to accelerate action towards sustainable energy for all. Lastly, Power for All, a global coalition of more than 150 private and public organisations campaigning to deliver universal energy access before 2030 through the power of decentralised, renewable energy.

70 Murphy and Sharma (2014). Scaling up access to electricity: the case of lighting Africa

71 Member states: Burundi, Kenya, Rwanda, Tanzania, Uganda.

72 Turman-Bryant (2015). The Revenue, Climate, and Health Benefits of Tax Cuts

RECOMM-ENDATIONS FOR FUTURE RESEARCH

This report summarises what we know about the factors affecting affordability of energy access in Africa for low-income households. What is clear is that although a picture is emerging, it remains a relatively sketchy one. In our search we found little prior research specifically on affordability. As a consequence we often had to rely on related data, broader evidence, and extrapolated conclusions to provide the insights above. We believe that a specific initiative to gather multi-country data and perspectives direct from both current and potential consumers would yield significant further insight. In particular we believe this would help test some of the following research questions and hypotheses

Hypothesis 1: the poverty reach of energy products declines as we move up the energy ladder.

Why is this important?

Essentially, we expect that a higher proportion of pico-solar customers live in poverty than the customer base of higher-end products or services like solar home systems and mini-grid connections. As explored in this report, there is some evidence that gives a picture of poverty rates of different product bases. However, this data comes from different countries and there are other factors that affect uptake and adoption of these products, not least the national poverty rate and market available. Exploring this question would allow us to confirm who it is we are serving by investing in specific levels of service. We can use this as an opportunity to assess whether PAYG does make solar home systems more accessible for lower income families, which at present is largely unknown. How could we test this? We could survey customers of a range of energy products to collect information on poverty status, access to and approval of credit, male/female-headed household uptake. Critically we would interview prospective customers who chose not to buy (a perspective we currently have especially limited data on). Learning about who that group are, what reservations they had for purchase, and ultimately what prompted them to make the decision not to uptake, will help us to understand if customers of modern energy services look fundamentally different from traditional energy consumers, and how. This would also provide insight on how best to target and market to consumers who were not convinced enough to purchase/connect to solar energy. One option would be to conduct this with the customer base of a company that has multiple product offerings. For example, d.light sells a large range of energy products to suit different budgets and capability, from pico-solar lights right up to solar home systems. Reaching out to their customers in the same geography would allow us to confirm or question the above hypothesis. This could be conducted in multiple countries too. Using national poverty rates would help to ground the results in the landscape in which they are being seen. As we discussed in this report, the nuances of who is being served across Africa is shaped by external factors.

Hypothesis 2: low income customers are at greater risk when accessing credit.

Why is this important?

While the PAYG revolution has been hailed as the solution to making modern energy access available to lower income groups, considerably less attention has been paid to any possible negative implications. It is possible that there are households who manage to find the deposit amount for SHS (the sources of which - savings, friends, lumpy earnings - we will also investigate) but struggle to make the regular payments. This could mean that families who make the payments have to divert expenditure away from other important goods; food, education, health care. Ultimately it might have effects on their likelihood to purchase other solar products, slowing people from climbing the energy ladder. This is key for companies taking a bet that customers will be sticky and can be upsold to gradually over time. How could we test this? We would use this as an opportunity to fully develop a Lean Data question set that focuses on resilience and risk factors for families. Conducting surveys with customers of energy products accessed through credit, we would identify change in household income spent on energy. Looking at where sacrifices are made if spending is higher post-purchase. Assessing a family's resilience to shocks and coping mechanisms will help us understand risks. And looking to well-being outcomes we would assess confidence level of households to meet payment commitments. This would provide real insight to PAYG companies, perhaps particularly those struggling with a high Portfolio At Risk (PAR) proportion.

Hypothesis 3: affordability is not the most important driver of adoption

Why is this important?

As we highlighted in this report, there are many things which affect a family's access and willingness to purchase an energy product or service. When we applied the 4As framework to agricultural goods, advantage came out as the most significant driver of adoption. For energy we have yet to establish a ranking, or set of rankings for different customers or products. Reaching out to both customers and the wider public to gain insight on this will provide critical information to understand the landscape we're working in. How could we test this? We would conduct interviews with current energy customers to understand their profile with regards to prior knowledge, awareness, and exposure to solar energy. We will explore influence factors and what ultimately motivated the customer not just to purchase modern energy access but of that company specifically. For example, what was it about the d.light SHS that attracted the customer? Do customers care about warranties? Are they familiar with differences in quality? Are they confident to make purchase decisions in this area? We could also conduct market-based research with the general public to get a representative understanding of the population as a whole. Drivers of adoption are influenced by culture and environmental factors so ensuring we understand not just existing customers but potential customers will give insight in how best to target them. We would be particularly interested to explore these dimensions in the less developed markets of West Africa where the next wave of development is likely to come.

Hypothesis 4: women consume and value energy differently from men.

Why is this important?

Not much is known on how energy is used by different household members or how that affects day-to-day life. This affects the impact access to energy can have as well as how it may be valued by its users. Understanding gender dynamics within households helps us to gain insight into how best to target or reach specific segments of the population. Or rather, make products or services more appealing to these groups. As the main caregiver of children in the household, learning more about how women consume or prioritise energy access may provide insights into how to best reach them and where there are opportunities to build a future market. How could we test this? This could best tested in much the same way as the above research questions, ensuring gender access in respondent rates. Alongside this, we can ask specific questions of these customers or the public to understand the dynamics in specific households and gain insight into variance and trends.

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All you could ever want to read on energy in Africa

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