QUALITY COMMUNICATION

QUALITY ASSURANCE IN KENYA'S OFF-GRID LIGHTING MARKET

By

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ABSTRACT

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This investigation attempts to characterize the flow of quality assurance information in Kenya's off-grid lighting market in order to identify key opportunities for improving access to product information throughout the supply chain. While traditional energy access strategies have focused primarily on rural electrification, distributed generation strategies through solar lanterns, solar home systems, and micro-grids are gaining more visibility and consideration as viable alternatives to their fossil-fueled analogs. However, there is a recognized need for greater institutional support to avoid market spoilage and encourage adoption of these nascent technologies in virgin markets. In response to this need, Lighting Global has created a quality assurance framework to monitor the quality of solar products in off-grid markets and communicate this information to market stakeholders.

Distributors, wholesale traders, retailers, customers, and other stakeholders were interviewed to better understand how buyers make purchasing decisions and how access to quality assurance information could be improved through mechanisms like product testing reports, on-the-box labeling, or illustrated flip-books. This research finds that solar products are now a dominant presence in off-grid markets in Kenya, capturing

approximately 80% of the market share by sales revenue in the towns that were surveyed. A variety of information signals were observed in the market, including brand-recognition, word-of-mouth referrals, and on-the-box product performance claims. Simplified product specification sheets and illustrated flip books were identified as the mediums preferred by retailers for learning more about solar products and educating customers. While many of the observed signals reduce uncertainty for end-users, quality signals like warranties, quality seals, or consumer financing were determined to play unique roles in reducing risk for potential solar customers. With increased digital literacy and mobile coverage in Kenya, mobile-friendly websites and social media applications were highlighted as opportunities for engaging and sharing quality assurance information with retailers and end-users further down the supply chain.

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LIST OF ABBREVIATIONS

AR5	Fifth Assessment Report
ATL	Above the line
B2B	Business to business
B2C	Business to consumer
BTL	Below the line
CE	Conformité Européenne
CIA	Central Intelligence Committee
DC	Direct current
FMCG	Fast moving consumer good
GLP	Greenlight Planet
GSMA	Groupe Speciale Mobile Association
ICT	Information and communications technologies
IEA	International Energy Agency
IEC	International Electrotechnical Comission
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
LED	Light Emitting Diode
MFI	Microfinance institution
MENA	Middle East and North Africa
NGO	Non-governmental organization
ODK	Open data kit
OECD	Organisation for Economic Co-operation and Development
PAYG	Pay-as-you-go
PLS	Pico-powered lighting system
PV	Photovoltaic
QA	Quality assurance
SACCO	Savings and credit co-operative
SE4ALL	Sustainable Energy For All
SHS	Solar home system
SLCP	Short-lived climate pollutant
SSS	Standardized Specification Sheet
TTL	Through the line
UL	Underwriters Laboratory
VAT	Value-added tax

CHAPTER 1: INTRODUCTION

Lighting Global is an initiative of World Bank Group that aims to support the "sustainable growth of the international off-grid lighting market as a means of increasing energy access to people not connected to grid electricity" (Lighting Global 2015). While there are a variety of activities housed within Lighting Global—including business development services, stakeholder engagement, and the publication of market intelligence and technical notes—the quality assurance program is one of the core features of Lighting Global's work. Since its inception in 2009, Lighting Global has focused primarily on small solar lanterns that substitute easily for kerosene lamps in off-grid households. Lighting Global also interfaces with regional World Bank Group programs like Lighting Africa, Lighting Asia, and Lighting Pacific to expand support to markets in Africa and Asia (Lighting Global 2014).

Quality assurance (QA) is a core feature of Lighting Global’s support for the growing off-grid lighting market, and there is a recognized need for reliable information about product quality and performance as the market grows toward 10’s to 100’s of millions of users served. Fundamentally, QA is a process of ensuring that accurate and trusted information about product quality is available for those who need it: producers, buyers, regulators, and other market stakeholders. As an example, product testing leads to performance results that can be verified through a standardized specifications sheet for distributors who are considering a purchase.

This investigation aims at describing how QA information can be effectively captured and deployed throughout the modern supply chain. As the market evolves, there are new opportunities for strengthening QA activities. Research results include new insights on the role of information and communication technology (ICT) access, the emergence of recognized brands and large distributors, and broader awareness of pico-solar.[1] The opportunities identified herein build on the successful QA foundations of product testing and verification that are at the heart of the Lighting Global approach.

This work draws on a research effort from May through July of 2014 to understand the current dynamics of the off-grid lighting market in Kenya. An early target for the pilot of Lighting Africa, Kenya displays evidence of a shift from early-stage market entry to a more mature market for pico-solar. This investigation sought to understand the ways that pico-solar is supported, distributed, and sold in markets like Kenya that could provide leading examples for the broader global market.

The market share of quality-verified[2] pico-powered lighting systems has dramatically increased in western and southern areas of Kenya over the period of support from the Lighting Africa program. Based on evidence from this investigation, pico-solar products now represent ~80% of the "electric off-grid lighting" market[3] as measured by sales value, up from single digit percentages in 2009, and quality-verified products represent roughly 50% of the solar market. This rapid growth in market share for quality-

[1] In this investigation, pico-solar refers to solar lanterns and small (< 10 Watts) solar powered lighting systems that can include more than one light point, charge a mobile phone, or power a DC radio or fan.
[2] Products that meet the Lighting Global Minimum Quality Standards
[3] Defined as energy devices that can at least provide lighting service, are sold on a retail basis in a complete package, and may include rechargeable batteries or require primary disposable cells (including torches / flashlights).

assured solar and other solar products has been aided by support from the QA program and additional market support from Lighting Africa and other institutions, indicating a degree of success from these early market efforts. It was found that QA verification is required or contributes strongly to decisions at several core points of the supply chain (e.g. buying requirements for large buyers) that manifest down the supply chain through the availability of good quality products and increased retail demand.

While QA is a complex set of processes, here it is distilled into two core "flows of information" that work together to reduce uncertainty and risk in the market: monitoring quality so it can be understood and verified by high-level supply chain actors and institutions (like manufacturers and programs like Lighting Global), and communicating verified quality to buyers and other decision-makers in the supply chain. When both mechanisms are working well, buyers can trust that the products they are purchasing will perform as advertised and provide a reasonable service life. Both elements of QA were observed in the market, closely linked with the structure of particular distribution channels and ways that financing is provided.

1.1 Key Findings

Communicating Quality through the Supply Chain: Several strategies were explored that could enable Lighting Africa to improve its communication of product quality information to consumers and supply chain stakeholders. These included radio advertising for consumer awareness campaigns, product specification sheets and flip books for distributors and retailers, and the use of electronic communication to connect

with an increasingly digitally literate market. Specifications sheets and clearly designed flip books were preferred by both retailers and distributors as tools for conveying quality information to buyers.

Signaling Quality to Buyers: Both “traditional QA” quality signals (e.g. product specification sheets and on-the-box performance reporting) and non-traditional quality signals like warranties and consumer financing were investigated. It was found that on-the-box reporting and online communications were the preferred means of communicating quality information for distributors. Actionable warranties and pay-as-you-go (PAYG) financing can also serve as quality signals for buyers, since they spread the risk of early failure more equitably between sellers and retail buyers. A combination of these mechanisms for signaling quality to buyers is present in the market, with the mix of information evolving along with the broader market.

Building Brands: A core feature of the way retailers and customers recognize good and bad quality products is through brand-recognition and brand-loyalty. Notably in Kenya, the d.light brand (and particularly the S2 model promoted heavily by d.light and SunnyMoney, the largest distributor of pico-solar products) is widely recognized on a retail level. Although the S2 was readily identified by its brand name ("d.light") in interviews with retailers and end-users, it was clear that the form factor—the product's shape and physical attributes—played an important role in product identification. A number of “counterfeit” products were found in the market that look very much like the ubiquitous d.light S2 but with different branding, responding to the form factor loyalty that has been created around the product. Distributors and retailers in the Kenya market

attribute the success of d.light S2 and its copycats to early adoption through broad institutional sales (it was the core model sold by SunnyMoney schools programs for a critical period of market growth), broad advertising efforts, and low price points.

Availability and Choices: The distribution of quality-verified products in distributor, proprietary, franchise, and NGO distribution channels has expanded greatly, due in part to reaching key decision makers higher up the supply chain with QA. Over 63% of retailers cited distributors as the main source of information about new products. Decisions made by distributors ultimately determine the products and opportunities for comparison shopping that are available to end-users, indicating that distributor and retailer networks should remain a core focus area for QA engagement. One sales channel with a notable absence of products that meet the Lighting Global quality standards was identified: the large, legacy wholesale electronics marketers in Nairobi that import electronics goods to Kenya. While specialty distributors that focus on pico-solar have been central to the market's growth, the wholesaler traders could play a unique role in facilitating the large-scale distribution of solar products to small retailers from rural areas through existing channels.

The Importance of Nimble QA: One of the biggest challenges facing pico-solar products is the fact that they are essentially consumer durables in competition and co-mingled with fast-moving consumer goods (FMCG) like kerosene lamps or torches. Pico-solar sales have increased dramatically in distribution channels where creative distribution and financing strategies allow customers to access and purchase pico-solar products more like an FMCG. Traditional QA for electronics is focused on the consumer

durables market, and for QA to support rapid growth in pico-solar there need to be "nimble" strategies for monitoring and communicating quality that can scale with and respond to the market. Accelerated testing and novel avenues for verifying quality should continue to be priorities for QA support of the market. For example, products employing mobile connectivity for PAYG can also capture remote in-field monitoring to verify ongoing product operation and offer responsive after-sales support.[4]

Given the complexities of product and information flows in the off-grid lighting supply chain, an effective QA program must employ a variety of strategies for monitoring the quality of products and communicating QA information to market stakeholders throughout the supply chain (Duke et al. 2002). This research will consider the influence of QA information in creating quality (prior to market entry), delivering quality (impacts on product distribution and financing), reducing uncertainty through direct and indirect signals, and reducing risk through Quality Signals. Finally, this research will conclude with a discussion of recommendations for the QA program going forward.

[4] Please see the forthcoming report by Alstone et al., "Off-Grid Power and Connectivity: Pay-as-you-go financing and digital supply chains for pico-solar."

CHAPTER 2: QUALITY ASSURANCE FOR THE OFF-GRID MARKET

For most countries belonging to the Organization for Economic Co-operation and Development (OECD), quality assurance (QA) and warranty mechanisms are safeguards that operate in the background of the modern manufacturing and sales industries. Although the average consumer is scarcely aware of them, certifications from the Underwriters Laboratory (UL) or trade associations ensure that the products that make it to market are safe and in compliance with a variety of national and international quality standards (Jacobson 2014). In addition, customers are generally able to return faulty products for repair, exchange, or refund, although the quality of response can vary (Harper et al. 2013). An effective QA framework therefore employs three distinct mechanisms for protecting consumers: voluntary or compulsory product testing, a reliable warranty program, and repercussions for poor quality products or poor warranty servicing. Product testing serves as a preventative measure to protect consumers from low-quality products before they make it to market. However, if low quality or unsafe products are sold to consumers, the company can be held accountable through a warranty program, legal repercussions, or the rejection of their brand by consumers. Thus product testing, warranty servicing, and legal repercussions must work in tandem as institutional mechanisms in order to effectively safeguard consumer interests.

But what about non-OECD countries? What does quality assurance look like in markets where product testing, legal enforcement, or consumer protections are underdeveloped (see Figure 1)? How can companies be held liable for low-quality or

unsafe products where there is little brand-recognition or where access to information about product quality or performance is limited?

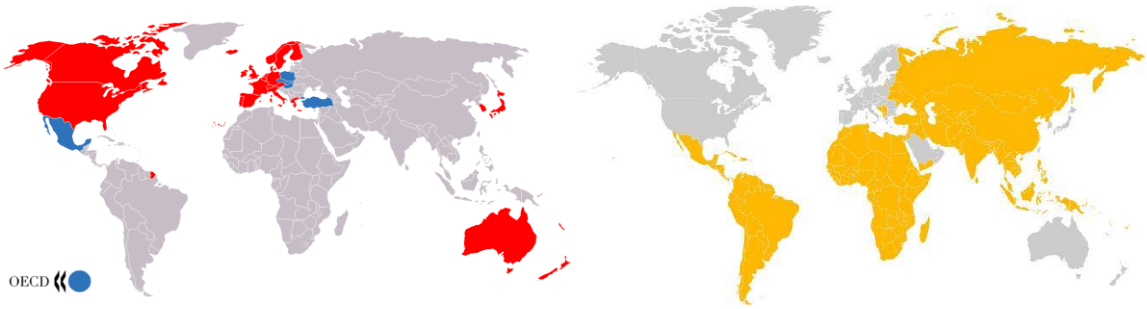

Figure 1: Left: countries belonging to the Organisation for Economic Co-operation and Development (OECD); Right: non-OECD countries (Jacobson 2014).

Given the particular constraints facing off-grid lighting markets, Lighting Global has developed a QA framework that includes rigorous testing for products before and after they reach the market and various mechanisms for communicating information about product quality and performance to buyers, retailers, investors, and other market stakeholders. In the end, the goal of the QA framework is to support good quality products and prevent market spoilage from bad buying experiences. The approach seeks to increase the visibility of high quality lighting products in the market while helping individuals and businesses in the off-grid lighting supply chain make informed decisions about the products that they are purchasing.

2.1 Multi-tiered Energy Access Strategies

In order to achieve universal energy access by 2030, the International Energy Agency (IEA) acknowledges that 60% of added electrical capacity will likely come from

decentralized generation sources. However, definitions of "energy access" and the projected pathways toward its achievement are often only vaguely defined (IEA 2010). The more recent Sustainable Energy for All Initiative has advanced the conversation beyond the traditional energy access binary (i.e. tied to grid / not tied to grid) by developing a multi-tier approach for measuring energy access, including factors like capacity, duration, reliability, quality, affordability, legality, and health and safety (see Table 1). However, there is still a need to define cost-effective pathways to reliable energy access that can provide needed energy services to end-users (e.g. lighting, mobile charging, etc.) and readily scale with increasing demand (see Table 2).

Table 1: Matrix for measuring household access to electricity supply and electricity services (SE4ALL 2015). Estimates of affordability are based on the approximate costs of electricity connection and consumption compared to local ability to pay. Legality refers to the "[i]llegal and secondary connections [that] serve a significant proportion of the population in many countries, representing lost revenues for the utility and posing a safety hazard" (SE4ALL 2015). Affordable and legal electricity connections are necessary but not sufficient conditions for the Tier 2 and Tier 3 energy access thresholds. While there are a variety of affordable and legal energy access options for the Tier 0 and Tier 1 thresholds, affordability and legality are not considered necessary conditions in the current framework.

Attributes	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Quantity (peak available capacity)	—	> 1 W	> 50 W	> 200 W	> 2000 W	> 2000 W
Duration of supply (hours)	—	> 4 hrs	> 4 hrs	> 8 hrs	> 16 hrs	> 22 hrs
Evening supply	—	> 2 hrs	> 2 hrs	> 2 hrs	4 hrs	4 hrs
Affordability (of a standard consumption package)	—	—	Affordable	Affordable	Affordable	Affordable
Legality	—	—	—	Legal	Legal	Legal
Quality (voltage)	—	—	—	Adequate	Adequate	Adequate

Table 2: Electricity services and devices associated with each access tier (SE4ALL 2015).

Device	Wattage	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Radio	1		X	X	X	X	X
Task lighting	1		X	X	X	X	X
Phone charging	1		X	X	X	X	X
General lighting	18			X	X	X	X
Air circulation	15			X	X	X	X
Television	20			X	X	X	X
Computing	70			X	X	X	X
Printing	45			X	X	X	X
Air cooling	240				X	X	X
Food processing	200				X	X	X
Rice cooking	400				X	X	X
Washing machine	500				X	X	X
Water pump	500					X	X
Refrigeration	300					X	X
Ironing	1100					X	X
Microwave	1100					X	X
Water heating	1500					X	X
Air condition.	1100						X
Space heating	1500						X
Electric cooking	1100						X
POTENTIAL DEVICES	—	Dry cell battery Solar lantern Rechargeable batteries Solar home system Mini-grid / grid	— Solar lantern Rechargeable batteries Home system Mini-grid / grid	— — Rechargeable batteries Home system Mini-grid / grid	— — — Home system Mini-grid / grid	— — — Home system Mini-grid / grid	— — — Home system Mini-grid / grid

The High Cost of Kerosene

Kerosene is still the most common source of light for the 250 million households lacking reliable access to electricity, but its utility comes at a cost: higher energy prices for poor families, climate forcing from black carbon emissions, particulate matter that contribute to tuberculosis and cataracts, and risks of child poisoning, structural fires, and severe burns (Jacobson et al. 2013; Mills 2014).

In the case of Kenya, 73.5% of households reported using kerosene as their primary fuel source in 2006, and of those households, the vast majority (81.2%) used kerosene for lighting (Ondraczek 2012). As seen in Table 3, the absolute annual expenditure on kerosene represented about 3% (100 KSh/month) of the household budget for the poorest households and 1% (250 KSh/month) for 4th quartile households, with the median household spending 2% (156 KSh/month) of the household budget on kerosene each year. Given that kerosene prices can be 35% higher when purchased in smaller quantities or from rural vendors, the poorest and most remote households are often disproportionately impacted by the high cost of kerosene (Tracy 2012).

Table 3: Median expenditure on kerosene by quartile, absolute, and as a percentage of annual income. Based on KNBS, 2005/06 (Ondraczek et al. 2012).

Income Quartile	Absolute Monthly Expenditure (Ksh)*	Percent of Annual Income Spent on Fuel
1	100	2.91
2	150	2.30
3	200	1.96
4	250	1.26
Total	156	2.01

* Blank data entries for kerosene expenditure data for households that reported they were not using kerosene was set to 0 KSh. This reduces median monthly expenditure on kerosene from 160 KSh to the 156 KSh presented here (a reduction of 2.5%).

In addition to its expense, kerosene is also a potent source of CO_2 and black carbon. Recent evidence indicates that 7-9% of kerosene burned in simple wick lamps is converted to black carbon (Lam et al. 2012, see Figure 2). According to the most recent report (AR5) from the Intergovernmental Panel on Climate Change, black carbon is a particularly potent short-lived climate pollutant (SLCP) with a global warming potential that is 900 times greater than CO_2 on a 100-year time horizon and 3,400 times greater than CO_2 on a 20-year time horizon (IPCC 2014). With 4 to 25 billion liters of kerosene being consumed annually to provide lighting for unelectrified households, this represents almost 5 gigatons of CO_2-equivalent emissions over the next twenty years (Jacobson et al. 2013).[5]

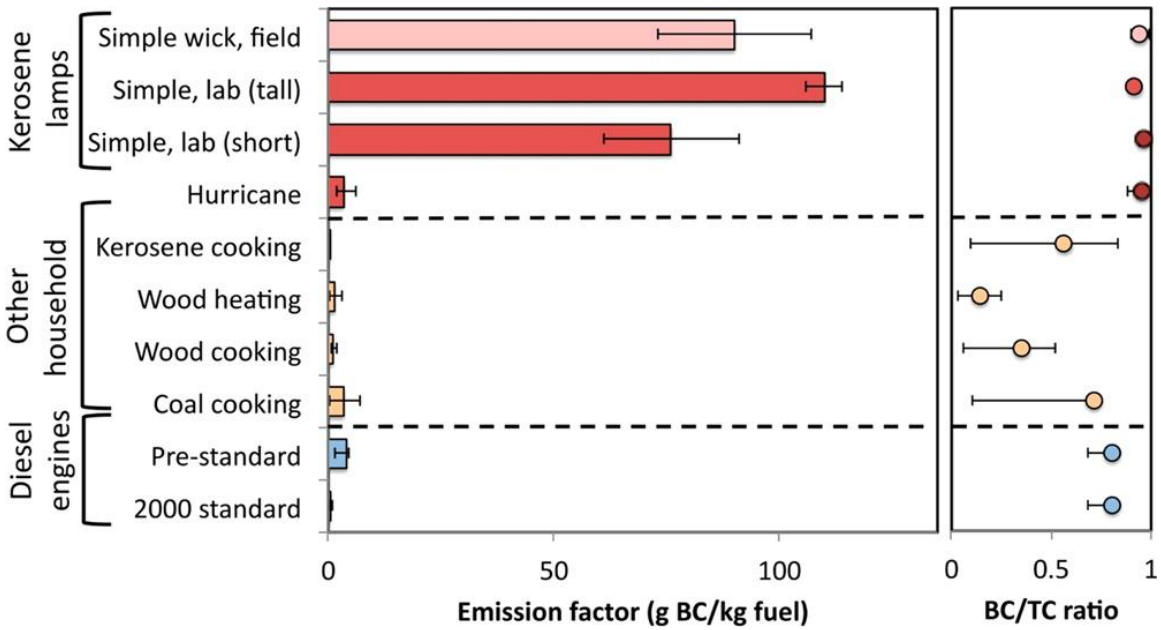

Figure 2: Comparison of emission factors for black carbon (EFBC) and black carbon fraction of total aerosol carbon (BC/TC) for kerosene lamps, other household uses, and diesel engines. Error bars represent 90% uncertainty bounds. Reproduced from Lam, et al., 2012.

[5] This estimate of global warming potential is based on the 100-year time horizon.

Taken together, a wick lamp can emit as much as 55 kg CO_2e each year, while a hurricane lamp can emit as much as 160 kg CO_2e each year.[6] As seen in Figure 3, black carbon has a strong radiative forcing impact over the regions where it is emitted, and an estimated 7% of all black carbon climate forcing comes from kerosene lamps (Lam et al. 2012). Given the scope of global kerosene emissions, the potential benefits associated with CO_2e reductions from kerosene lamps are substantial for the 250 million households without electricity.

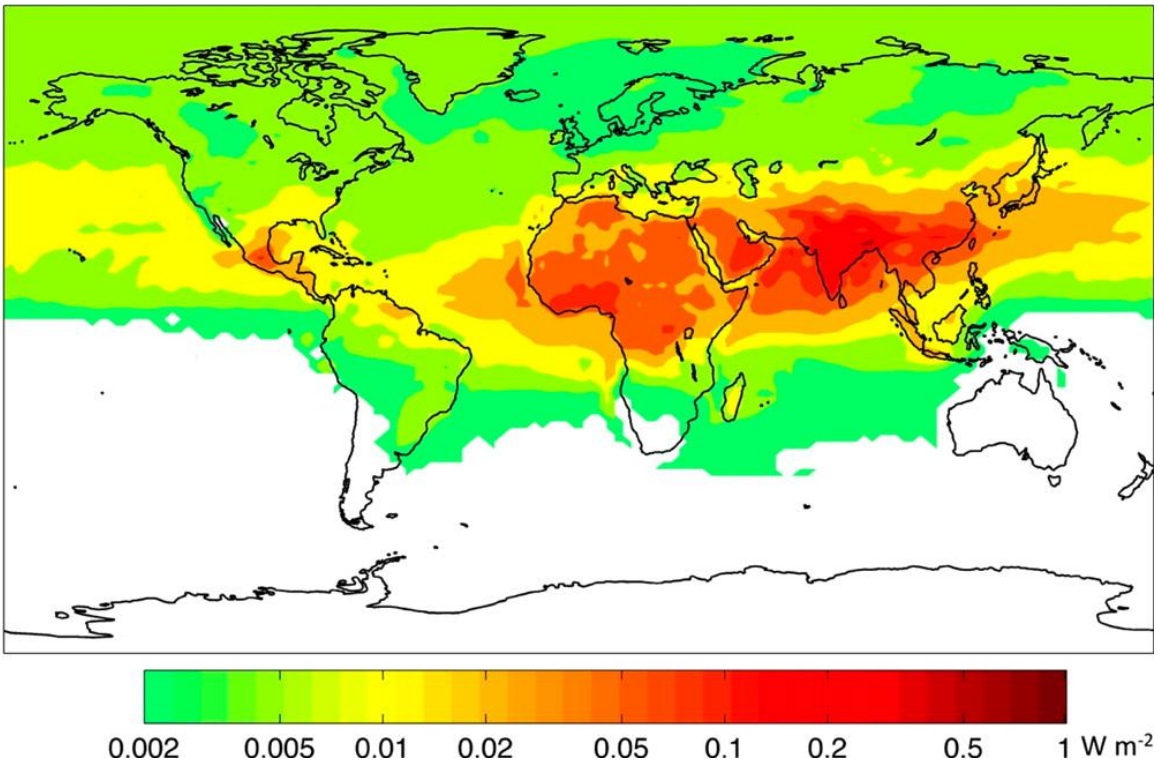

Figure 3: Direct black carbon radiative forcing from residential kerosene lighting (W/m^2). Reproduced from Lam et al., 2012.

[6] The following assumptions were made in the calculation of kerosene lamp emissions: (1) Given an average of four hours of use per day, a simple wick lamp consumes approximately 13 liters of kerosene in a year compared to 38 liters of kerosene for a hurricane lamp; (2) Approximately 0.068 kg CO2 are emitted per megajoule of kerosene; and (3) Approximately 8% of kerosene is converted into black carbon, and black carbon has a global warming potential that is 900 times the global warming potential of CO2 (Mills 2003; IPCC 2014).

However, the cost of kerosene is not limited to energy service expense. Individuals using simple wick lamps are often exposed to concentrations of $PM_{2.5}$ that are an order of magnitude greater than World Health Organization guidelines, which often result in impaired lung function and increased risk for respiratory disease, cancer, eye problems, and infectious disease (Mills 2012; Tedsen 2013). There are also risks associated with fires in buildings that result in severe burns and particularly high death rates (24% on average) or the premature death of children from unintentional ingestion of kerosene (Mills 2012). While efforts have been made to quantify the co-benefits associated with $PM_{2.5}$ emission reductions, much of this research has focused on outdoor air quality in industrialized nations. Although one study claims that "individuals breathing particulate-laden kerosene fumes inhale the toxic equivalent of smoke from two packs of cigarettes a day," much of the evidence regarding indoor air pollution is anecdotal and difficult to quantify in economic terms (Lighting Africa 2010:15).

The Benefits of Pico-Solar

Although kerosene provides a needed energy service for poor and remote households without electricity, its impact on household income, public health, and climate is considerable. Fortunately, pico-solar products that combine photovoltaic cells with light emitting diodes (LEDs) represent a promising alternative to kerosene wick lamps. With a rapid payback (20 to 50 days) and an extended lifespan (approximately two years), pico-solar products are able to provide a superior energy service that is less expensive, less polluting, and less dangerous than kerosene (Alstone et al. 2014). Also,

unlike other emitters of black carbon like diesel engines or industrial coal burning, pico-solar products provide a viable alternative to kerosene that could rapidly reduce radiative forcing from black carbon (Tedsen 2013). However, despite dramatic growth in pico-solar sales in Africa (90-95% year-on-year), there are still significant obstacles that must be overcome in order for pico-solar to rapidly and permanently displace kerosene as the main source of lighting in off-grid markets (Dahlberg 2012). These barriers include lack of consumer-level financing, poor product quality, lack of after-sales service, lack of customer awareness, and taxes and subsidies that distort market incentives (Lighting Africa 2010). While many of the former barriers have been considered in previous studies, the impact of quality assurance information access on pico-solar sales is the subject of this study.

2.2 Information Flow in the Supply Chain

In their recent book on data-driven development interventions, Abhijit Banerjee and Esther Duflo find that the poor represented in their sixteen-country dataset "often lack critical pieces of information and believe things that are not true" (Banerjee and Duflo 2012:268). Looking at the examples of immunizing children, early-childhood education, fertilizer use, or HIV infection, they argue that the poor often face information constraints that impede their ability to make decisions that would contribute toward personal and societal welfare.

Capital-constrained customers in off-grid markets face a similar dilemma when trying to purchase a lighting product without knowing much about its quality or utility. In

general, access to information about product quality and performance plays a central role in the development, marketing, and sale of off-grid lighting products. When information flows freely up and down the supply chain, investors and buyers are able to make informed investment and purchasing decisions, and manufacturers are able to develop and improve product design based on customer feedback and outcomes from the field. In the absence of information about product quality or durability, investors and buyers must rely on direct experience or anecdotal evidence, often arresting the introduction or adoption of new or unproven technologies like solar lanterns. Market spoilage, which was documented in the early development of the Kenya market, occurs when consumers lose confidence in a new technology based on bad experiences with poor-quality products or when manufacturers are disconnected from the realities of how their products perform in the real world (Mills et al. 2014).

In this regard the inability of information to flow freely through the supply chain and the inequitable distribution of that information to supply chain actors are both potent examples of a market failure caused by information asymmetry. Information asymmetry was first explored by George Akerlof (1970) in his seminal paper, "The Market for Lemons: Quality Uncertainty and the Market Mechanism." Using used car sales as a model for this theory, Akerlof demonstrates how the asymmetric distribution of information in the market—where buyers know more than sellers about the quality of the goods being sold—can encourage the sale of low-quality goods and engender consumer distrust. Therefore, in markets where it is difficult to distinguish between high and low quality goods, uncertainty about product quality artificially suppresses the buyer's

willingness to pay, which makes it more difficult for high quality products to compete in an information-constrained market.

2.2.1 Responses to Information Asymmetry

Given that information asymmetry in a market results in the overall degradation of value of those goods, there are a variety of mechanisms that attempt to correct for this imbalance. For example, Michael Spence first examined how information asymmetry in the job market is often balanced through an applicant's use of signals: "observable characteristics attached to the individual that are subject to manipulation" by the applicant and that are typically costly to send (e.g. having a college education as proof of competency or diligence) (Spence 1973). Similarly, Joseph Stiglitz (1975) first developed the theory of screening whereby information asymmetry is balanced when uninformed parties can induce the informed parties to share that information (e.g. insurance companies that offer lower premiums for different risk classes). More broadly, Stiglitz and Greenwald argued that "economies in which there are incomplete markets and imperfect information are not, in general, Pareto efficient" (Greenwald and Stiglitz 1986). In other words, in markets where information is asymmetrically distributed, the invisible hand of the market does not provide the most efficient allocation of resources, and some form of intervention (e.g. government policies, taxes, or subsidies) can be used to more effectively distribute information to market stakeholders.

But which intervention is most appropriate, and how should the corrective be applied? Richard Duke, Arne Jacobson, and Daniel Kammen (2002) explored several

potential correctives to information asymmetry in the solar module market in Kenya. Similar to used cars, it is difficult to determine the relative quality or performance of a solar module before its purchase. Even when suboptimal performance is experienced in an off-grid solar system—for example, when a battery fails prematurely—it is difficult to determine whether the failure was due to user error, a low quality battery, or a low quality solar module. In addition, their field investigation revealed that the inability of PV vendors and technicians to measure module performance and a lack of brand awareness among PV customers also contributed to the inability to discriminate between high and low quality modules in the Kenyan market. Given the risk of financial loss and the depressed "pooled quality" expectation of consumers, they identified six corrective options for restoring information balance in the PV module market: reputation signaling through advertising and branding, warranties, performance testing and disclosure, certification and labeling, minimum quality standards, and alternative business models.

Png and Reitman provide support for the claim that branding can signal quality for experience goods. These are goods for which the quality cannot be determined based on inspection (Png and Reitman 1995). In their analysis of sales and demographic data from branded and unbranded gasoline stations, they find a greater density of branded gasoline stations in areas where "consumers find personal search and experimentation relatively unattractive" (e.g. zip codes with greater than average incomes or stations near highways where there are more non-local customers). In other words, branding can signal quality to customers that cannot afford to spend time verifying its authenticity, but branding is less necessary when performance can be validated or when financial risk is

low. For example, it is not surprising that many of the cheap torches that are available in the off-grid lighting market carry non-descript or generic brands names because consumers can afford to try different keychain lights and dry-cell battery torches without risking significant financial loss. In contrast, many of the off-grid lighting products rely on branding to signal a level of quality that is worth the additional financial risk that the consumer must make to experience the product. Taken in this light, branding can serve as an effective quality signal in mature markets where consumers are generally aware of different products and the quality of service that they provide. However, in emerging markets where there is limited consumer awareness, branding on its own may not be sufficient to reduce the financial risk or uncertainty about a light's utility for new customers.

Similarly, Hayne Leland argues that minimum quality standards can reduce information asymmetries in a market but are most advantageous for products with an inelastic demand, a high sensitivity to average quality, and low costs for providing quality (Leland 1979). Furthermore, he argues that minimum quality standards should ideally be set by a third-party, as the imposition of minimum quality standards by a professional group or industry could result in the standards being set too high (making entry more difficult for new products) or too low (relaxing enforcement). However, it is important to note that Leland's analysis assumes that only products meeting the minimum quality standard are allowed in the market, and thus it is not fully applicable to off-grid markets where enforcement of minimum quality standards may not be a safe assumption.

Finally, Thomas Cooper argues that a flexible policy of signal facilitation can be preferable to mandated testing and disclosure of information in markets with information asymmetry (Cooper 1992). Cooper examines different warranty scenarios for used car sales and finds that policies that mandate the testing and disclosure of used cars would be too costly for dealers. Alternatively, Cooper argues that an effective policy that optimizes social welfare provides an incentive structure that encourages signaling without sacrificing flexibility. For example, dealers can be induced to provide warranties for used cars by increasing the penalty for signaling falsely, but the ultimate decision about how and whether to disclose information about quality would reside with the dealer. Unfortunately, enforcement of these penalties is challenging in off-grid markets like Kenya, but there are a variety of incentives that can be provided to manufacturers and distributors to facilitate the disclosure of information about product quality and performance. As we will see, although there are information gaps that continue to persist in off-grid lighting markets in Kenya, many of the correctives mentioned above are currently being implemented to reduce information asymmetry and uncertainty for buyers.

2.2.2 Information Mediums

As a consumer protection mechanism, the flow of information about product quality and performance can be as simple as a word-of-mouth recommendation and as complex as an international quality standard enforced by government regulators and inspectors. In both cases information can reduce risk and uncertainty for buyers and

consumers by addressing the central QA questions: Will this product perform as advertised? Will it last? Is it worthy of investment?

Despite sharing the same goal, not all information mediums are created equal. A television advertisement may reach a broader audience, but it does not carry as much weight as a personal recommendation from a trusted acquaintance. Traditional marketing distinguishes between above-the-line (ATL) and below-the-line (BTL) communications, where the former includes impersonalized mass media like television or radio advertisements and the latter includes more personalized promotions like road shows or product demonstrations. More recent trends in relationship marketing have emphasized the need to promote through-the-line (TTL) by raising the awareness of consumers through mass media campaigns and engaging interested customers through personalized messages and building brand communities (Daly and Malony 2004; Laroche et al. 2012).

Although imprecise, this distinction between communication mediums is nonetheless useful, as the more personalized and trustworthy the information, the greater the impact on consumer behavior. Moreover, the flow of information through the supply chain is evolving dynamically with the rapid development and proliferation of information and communication technologies (ICTs) like mobile phones and internet services. A key finding of this investigation is that information and communication technologies like mobile phones and social media apps can simultaneously expand the reach and impact of QA information by grafting impersonal, institutional messages into personalized, relational networks that carry weight with end-users. Combined with the increasing digital literacy of rural customers, the channels for information flow that have

been opened up by information and communication technologies represent one of the most important opportunities for improving quality assurance in the market.

2.2.3 Reducing Uncertainty vs. Reducing Risk

Despite the increased presence of ICTs, off-grid markets are still particularly vulnerable to information asymmetry, where buyers know much less than sellers about the quality or performance of products in the market. Given the uncertainty or risk associated with the investment, a buyer must rely on a variety of sources and signals to determine the product's relative quality or utility. While some of these signals reduce uncertainty by indicating how the product performs or how suitable the product will be for the buyer's needs, other signals reduce risk by indicating the product's quality or durability.

For the purpose of this research, signals that reduce uncertainty will be characterized as either indirect or direct. Indirect signals like product presence, branding, or word-of-mouth referrals are sources of information that cannot be directly controlled by the seller but still inform and influence consumer behavior. Direct signals like advertising, on-the-box reporting, and sales tools are sources of information that require a specific action or effort on the part of the seller. While both direct and indirect signals reduce uncertainty by communicating information about the product (e.g. its utility, desirability, or performance), this information is not always a reliable indicator of quality. Thus, quality signals like quality seals, warranties, or consumer financing play a unique role in reducing risk and safeguarding consumer interests in off-grid markets.

2.3 The Lighting Global Quality Assurance Framework

Since its inception in 2009, the QA program has been guided by five market-driven principles:

1. **Affordability**: Seek an appropriate balance between quality and affordability.
2. **Diversity and Innovation**: Allow for product diversity in technology, utility, and price; encourage innovation by using non-prescriptive, performance-based metrics and goals.
3. **Rigor**: Develop rigorous testing standards that can be carried out using reasonably low-cost instruments; provide technically valid test results that can be accepted globally.
4. **Stability**: Maintain stable and transparent QA policies so stakeholders know what to expect.
5. **Insight**: Effectively communicate key product quality and performance information so buyers can make informed purchasing decisions.

(Lighting Global 2014)

Lighting Global has contributed toward the publication of two international quality assurance standards through the International Electrotechnical Commission (IEC), the development of five testing laboratories, engagement with more than 40 manufacturers, the verification of 47 products that meet the quality standards, and the sale of over seven million quality-verified products.

The Lighting Global QA program consists of three main components: developing and publishing test methods and quality standards, product testing and verification, and communicating quality to the market. Each of these components is interdependent, as the test methods define the quality standards and methodology associated with product testing (see Table 4).

In addition, the communication of QA information to stakeholders improves the visibility of quality-verified products in the market to inform design, investment, deployment, and purchasing decisions throughout the supply chain.

Table 4: Summary of the testing framework used by the quality assurance program (Lighting Global 2014).

Component Tests	Sampling	- Randomly selected from warehouse or marketplace
	Photometrics	- Luminous flux (lumens—total light output) - Standardized distribution (illuminance)
	Battery & Charge Control	- Battery capacity (amp-hours) - Protection (voltage cutoffs and durability)
	Solar Module	- Power output (watts) - Current-voltage characteristics (I-V curve)
System Tests	Full-Battery Run Time	- Measured using standardized cycle (hours of operation)
	Solar-Charge Run Time	- Modelled estimate (daily hours of operation after solar charging)
	Physical Ingress & Water Protection	- Incorporates enclosure (IP class) and system-level protection (coatings, etc.)
	Durability	- Drop test from one meter (pass/fail) - Switch and connector durability - Internal wiring and solder inspection - Lumen maintenance - Battery storage durability

Currently, Lighting Global has four distinct mechanisms for communicating information about product quality and performance: engagement with manufacturers, distributors, and other key market stakeholders in the supply chain; regional consumer awareness campaigns; product specification sheets and technical notes on the Lighting

Global website; and on-the-package reporting and labeling requirements. Quality-verified products receive a standardized specification sheet (SSS) and a verification letter that can be used as proof of meeting the quality standards. Table 5 provides a summary of the different communication strategies and outreach efforts that Lighting Global employs to engage with stakeholders throughout the supply chain.

Table 5: Methods used by Lighting Global and regional programs to engage with market stakeholders (Lighting Global 2014).

Stakeholder	Communication Method
Consumers	Advertising campaigns and consumer education conducted by regional programs; SSS and website in cases where consumers have access
Manufacturers	Test reports, SSS, direct outreach by personnel associated with the Lighting Global, Lighting Africa, and Lighting Asia programs
Distributors, finance and microfinance, retailers, bulk purchasers, NGOs	SSS, website, direct outreach by personnel associated with the Lighting Global, Lighting Africa, and Lighting Asia programs
Governments (e.g. customs officials)	Verification Letters, SSS, website, direct outreach by personnel associated with the Lighting Global, Lighting Africa, and Lighting Asia programs

The QA program described above has provided a solid foundation on which Lighting Global continues to revise and expand its support of solar products in a rapidly growing and evolving off-grid market. Notably, Lighting Global is working with manufacturers and the IEC to finalize an international quality standard and testing methodology for solar home systems that can provide superior energy services through increased lighting, mobile charging, fans, radios, low-power televisions, and other DC

appliances. In this way, the QA program will continue to play a central role in the development and deployment of technologies that can satisfy the demand for energy devices and services that conform to a multi-tiered energy access paradigm.

2.4 Kenya as a Case Study

As previously stated, Kenya was chosen for this study because Kenya is one of the market leaders for pico-powered lighting systems (PLSs) in Africa and because the Lighting Africa program originally started in Kenya in 2009. Interviews and surveys were conducted in five different counties in Kenya from May to July of 2014. As of 2014, Kenya had an estimated population of 45 million people, with 76 percent residing in rural areas and approximately 43 percent living below the poverty line (CIA 2014). While the Rural Electrification Authority (REA) of Kenya estimates that 35% of the population was connected to electricity as of June, 2014, other sources indicate that grid connectivity may be as low as 19% (Ministry of Energy and Petroleum 2015; Ministry of Public Health and Sanitation 2010). This discrepancy in estimates is likely due to governmental pressures to meet electrification goals (greater than 65% by 2020) as well as the large number of households that are situated near power lines that have unreliable or illegal connections to the grid (Africa Electrification Initiative 2012; Lee et al. 2014).

CHAPTER 3. STUDY METHODOLOGY

This research was conducted through the Schatz Energy Research Center at Humboldt State University in partnership with the Renewable and Appropriate Energy Laboratory at the University of California, Berkeley. From May through July of 2014, I worked with two researchers from Berkeley, one off-grid lighting consultant, and three field researchers over the course of two months. In order to map the flow of products, information, and finance through the off-grid lighting supply chain in Kenya, our research team partnered with several NGOs and businesses to conduct over four hundred surveys with consumers, retailers, distributors, finance providers, manufacturers, and non-profit organizations. Surveys were conducted in-person across Kenya, Germany, and the United Kingdom and over the phone from the United States and the United Kingdom. These key informant interviews were conducted across the supply chain for off-grid lighting, from global head offices to regional distribution houses.

Detailed in-person surveys (approximately 130) were also undertaken at the retail level for sellers of both quality-verified and unverified off-grid lighting products.[7] This mixed methods approach gave our team unique insight to the contemporary market, particularly in Kenya. In addition, the research team partnered with SunnyMoney and M-KOPA to conduct interviews with 58 pico-solar customers and 86 solar home system customers, respectively. These interviews were primarily focused on pay-as-you-go (PAYG) financing and digital literacy among each organization's customer base. Finally,

[7] The surveys and overall research plan were approved by the Humboldt State University Institutional Review Board (Human Subjects protocol number 13-152).

two focus groups were conducted with SunnyMoney customers to learn more about what customers think of PAYG financing and data collection from PAYG devices. Please see Table 6 for a summary of the data collection efforts associated with this research endeavor.

Table 6: Description of data collection efforts from Kenya off-grid market research.

Data Collection Effort	Sample Size	Sample Selection	Description of Data Collected
Retailer Surveys	130	Census	Demographic ICT usage Quality assurance preferences Supply chain information Product information Sales data
Distributor Surveys	14	Census	Demographic ICT usage Quality assurance preferences Supply chain information Product information Sales estimates
Focus Groups	24	Gender distribution; availability	Product performance PAYG impressions Data preferences
Baseline Pico-Solar Customer Surveys	58	Random	Demographic Baseline energy usage ICT usage Purchase influences
Follow-up Pico-Solar Customer Surveys	50	Random	Demographic Current energy usage Solar light impressions Solar light impacts PAYG impressions
Solar Home System Customer Surveys	86	Random	Demographic Energy usage ICT usage SHS impressions Purchase influences PAYG impressions

3.1 Retailer and Distributor Interviews

While there were a variety of research collection efforts conducted during this investigation, the results from the retailer and distributor interviews are most relevant to the topic of quality assurance.[8] The methodology for surveying and interviewing retailers and distributors was based on two previous investigations of off-grid lighting that were conducted by Lighting Global researchers in Kenya in 2009 and 2012.[9] In the original investigation, three towns were selected to provide an in-depth characterization and analysis of off-grid lighting products and retailer demographics. Collecting data over the course of five years in these three distinct markets (urban, peri-urban, and off-grid) has provided our research team with unique insights into the growth and evolution of the off-grid lighting market in Kenya.

In each town, our team endeavored to survey every off-grid lighting retailer that could be found within a specific geographic boundary. The original boundaries were selected to capture the majority of off-grid lighting retailers in each town, and in each study the geographic boundaries have been expanded to incorporate evolving market conditions. In Kericho, the original survey area near the central park was expanded to include the informal traders and retailers at the *matatu*[10] stagecoach (see Figure 5). In Brooke and Talek, retailers from the previous survey areas were surveyed again (see Figure 6 and Figure 7). While this census style sampling limits the inference that can be

[8] Since there were a variety of research efforts being conducted simultaneously, it was not possible to include many questions related to quality assurance or purchasing preferences on end-user surveys.
[9] Please see "A Growing and Evolving Market for Off-Grid Lighting" by Harper, et al. (2013), for a more detailed description of surveying methodology.
[10] *Matatus* are privately owned minibuses used for transporting people and goods in Kenya.

made to other off-grid lighting markets in Kenya, it was determined that the advantages of an in-depth characterization of the off-grid lighting market in each town over time was preferable to trying to characterize the broader off-grid lighting market in Kenya through the random sampling of retailers in different regions.

In addition to the three towns that had been previously surveyed, Figure 8 provides an aerial image of the wholesale traders market in Nairobi where off-grid lighting retailers were also interviewed. A large number of rural and small town retailers purchase a variety of household wares and electronic items from the Luthuli Avenue, River Road, Nymakima, and Kamukunji markets in Nairobi because of the low pricing, proximity to interurban transport, and the variety of goods that can be purchased in one area. While some retailers were reluctant to disclose sales information in the other three towns where interviews were conducted, there were almost no retailers in the Luthuli Avenue area who were willing to share information about pricing or sales volume. This mistrust of outside scrutiny is likely due to a fear of being reported to the Kenya Bureau of Standards (KEBS) for inaccurately labeling or registering products or for selling products that may have circumvented customs through intra-Africa importing.[11] Retailers also expressed a reluctance to share pricing and sales information for fear that that information would be shared with other retailers in the market. Although it was clear that a lot of product moves through these wholesale markets, the lack of concrete sales data makes comparisons between markets speculative at best.

[11] Intra-Africa importing is a process whereby cargo that arrives at the port of Mombasa, Kenya is sent to a neighboring East African country (e.g. Uganda or Tanzania) before returning to Nairobi. Since the initial destination is outside of Kenya, the shipment is able to bypass customs and avoid import duties or value-added taxes (VATs).

Off-grid lighting retailers were defined as any retailer selling an off-grid lighting product. Off-grid lighting products were defined as products that have energy storage incorporated in the product (with dry-cell or rechargeable batteries) and have an LED, incandescent, fluorescent, or other electric lighting source. As a result, there was a great degree of variety within the retailers that were surveyed, with some shops selling only a few lighting products (i.e. small keychain lights or a single brand of solar lamp) and some shops specializing in off-grid lighting. Overall, approximately 58% of the retailers surveyed were located in Kericho, 18% were located in Talek, 13% were located in Nairobi, 11% were located in Brooke. In addition, as seen in Figure 4, the majority of shops were electrical or general shops, though many shops fit in more than one category. Also, 97% of the shops sold products on a retail basis, while 36% sold products on a wholesale basis (with some shops selling both wholesale and retail). Finally, 39% of the individuals who were interviewed were female, while 61% were male.

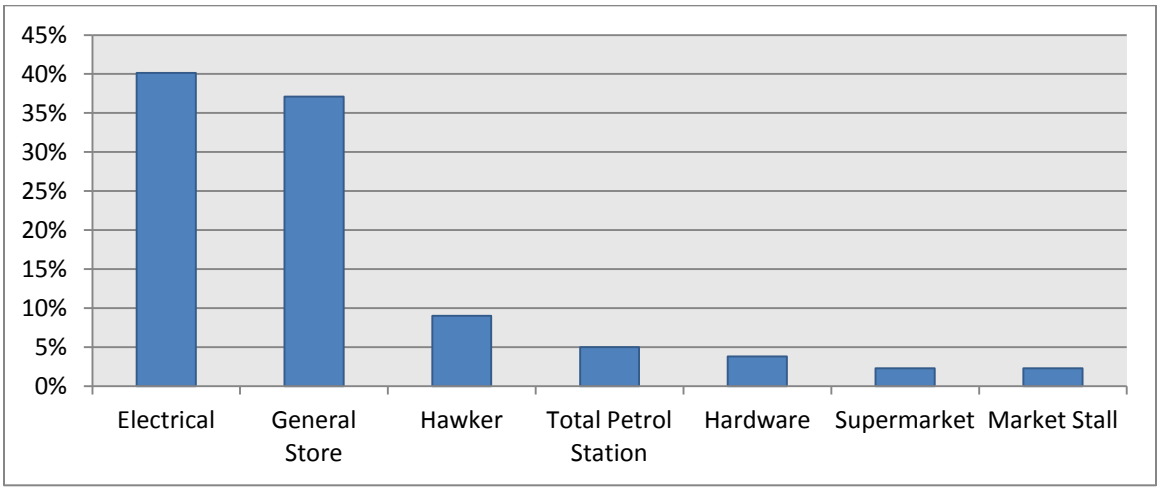

Figure 4: Types of shops that were selling off-grid lighting products and participated in the retailer surveys (N=132).

Distributors were selected based on information that could be gathered from interviews with manufacturers and Lighting Africa staff in Kenya. Given that Lighting Africa had already expended considerable effort in trying to connect with off-grid lighting distributors in Kenya, our selection of distributors was based in large part on the information that had been gathered by Lighting Africa staff. While there were attempts to engage with other distributors outside of the Lighting Africa purview—for example, the wholesale traders market on Luthuli Avenue in Nairobi and other distributors that were named during retailer interviews—these interviews represented more of a hybrid between our retailer and distributor surveys.

Retailer and distributor surveys were conducted using Open Data Kit (ODK) software on tablet computers. When possible surveys were conducted in English, but each non-Swahili speaking researcher was partnered with a local Swahili-speaking researcher to provide linguistic and cultural translation. There were a total of seven enumerators, four native Kenyans and three white foreigners. Not all enumerators were present in each town; for example, there were only four enumerators present in Talek and two enumerators present in Nairobi. While the presence of a white foreigner and the process of translating some of the surveys no doubt resulted in some confusion and mistranslation, our Kenyan field partners indicated that retailers were generally more forthcoming with information when a white foreigner was present than when the field partner tried to conduct the survey alone. This could be due to the previously mentioned fear of losing a competitive advantage (i.e. an individual Kenya could be working for government or another business, but a Kenyan with a white foreigner was perceived as

less threatening). Please see Appendix C for an example of the survey used when conducting retailer interviews. Surveys were processed using the formhub online platform for ODK data. Information was then cleaned and analyzed using Microsoft Excel and the R Statistical Package.

Figure 5: Aerial image of central Kericho (retrieved from Google Earth in 2015; imagery from 2015), with the boundary of the baseline market study indicated by a yellow dashed line and the matatu stagecoach area indicated by a red dashed line.

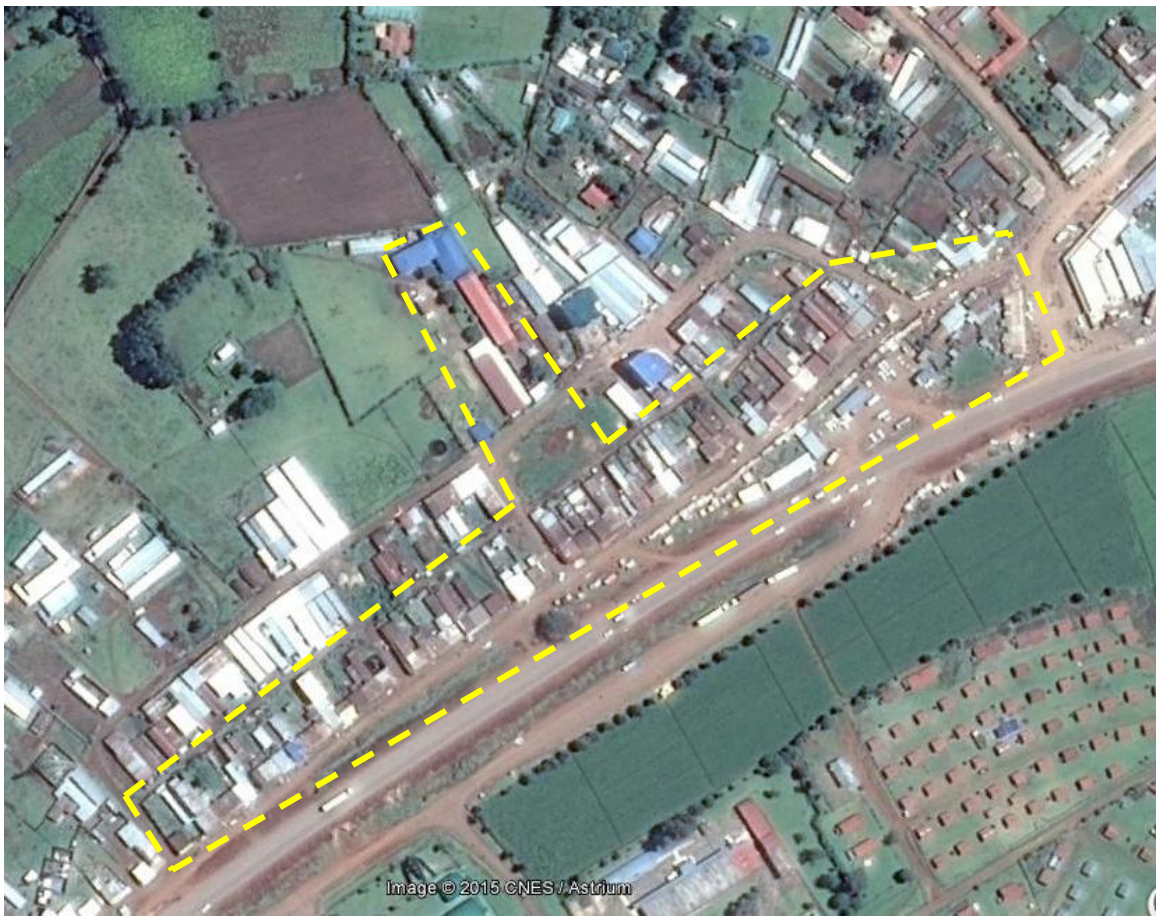

Figure 6: Aerial image of Brooke (retrieved from Google Earth in 2015; imagery from 2015), with the boundary of the baseline study indicated by the yellow dashed line.

Figure 7: Aerial image of Talek (Image retrieved from Bing Maps 2012) with boundaries from 2009 and 2012. The 2012 boundaries were used for the 2014 surveys (Harper et al. 2013).

Figure 8: Aerial image of Luthuli Avenue and River Road in Nairobi where wholesale electronics and household items are sold (retrieved from Google Earth in 2015; imagery from 2015), with the boundary of the baseline market study indicated by a yellow dashed line. The red dashed line demarcates the Nymakima wholesale market where household items and battery-powered and grid-charged lights are sold.

3.2 Other Data Collection Efforts

As previously stated, there were a variety of data collection efforts being conducted simultaneously during this investigation. In particular, the end-user surveys and focus groups aimed at gathering information related to pay-as-you-go (PAYG) financing for pico-solar products sold through SunnyMoney and M-KOPA. Respondents for these surveys were selected at random from each organization's database, and this list

was given to enumerators in each organization's call center. The SunnyMoney database from which the fifty-eight customers were selected included approximately 300 total participants from a particular school campaign. The M-KOPA database from which the eighty-six customers were selected included approximately 60,000 customers. Enumerators were trained in conducting surveys over the phone, and surveys forms were translated into English and Swahili so that the survey could be conducted in the customer's language of preference without requiring site translation. Survey responses were recorded using Google Forms, and the data was checked by a member from our research team to correct for missing or contradictory information. Participants in the two focus groups were selected based on their ability to meet. In addition, focus groups were divided by gender in order to ensure that the women would feel comfortable sharing their opinions.

CHAPTER 4: THE OFF-GRID LIGHTING SUPPLY CHAIN

While each product follows a particular path from the factory to the end-user, that path often depends as much on the flow of finance and information as it does on transportation infrastructure. Where products, information, and finance flow freely through the supply chain, supply chain actors are able to comparison shop, make informed decisions, and ultimately access the products and services that they need and want. In this sense, the flow of products, information, and finance are critical for understanding the various facets of energy access. Figure 9, below, captures the flow of products from their origin in Nairobi to their sale in urban, peri-urban, and rural markets.

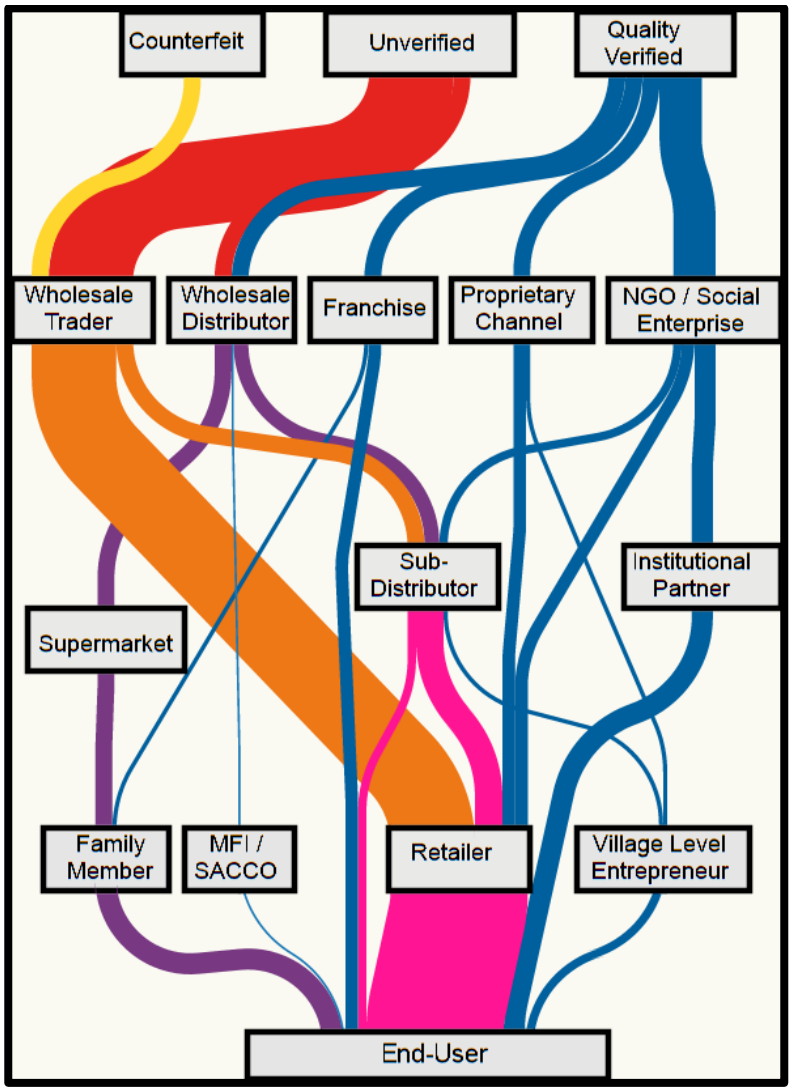

Figure 9: Distribution channels observed in the off-grid lighting supply chain in Kenya. The blue lines represent the flow of products that have met the Lighting Global quality standards; the red lines represent all other off-grid lighting products (including torches, key chain lights, emergency lights, etc.); and the yellow line represents the flow of counterfeit products. Gradations within the color scheme represent the confluence of different product flows (orange: unverified and counterfeit products; purple: quality-verified and unverified products; pink: quality-verified, unverified, and counterfeit products). Line width approximates the quantity of products flowing through each channel based on market observations and interviews with retailers, MFIs, and distributors for the three towns and the Nairobi wholesalers market that were surveyed. The product flows indicated may not be fully representative of national sales volumes for each category if sales in other regions differ from those in the regions covered in this study.

4.1 Six Core Sales Channels

Six core channels were identified through which pico-solar products were distributed in Kenya (summarized in Table 7). This investigation confirms previous findings that the majority of solar lighting products flow through distributor and retail channels, with most off-grid lighting products flowing through wholesale traders and wholesale distributors[12] first and then being sold to end-users by retailers[13] (Dahlberg 2012). A fraction of lighting products are sold through franchise distribution channels like Total petrol stations. In addition, family members can play an important role in conveying products from urban or peri-urban markets to relatives in rural areas. A large number of quality-verified products are sold through proprietary and NGO-partnership channels by companies like SunnyMoney and M-KOPA.[14] SunnyMoney notably sells more solar lights in Africa than any other company by combining institutional sales through schools with a developing network of sub-distributors that sell through traditional brick-and-mortar retail shops. With a few exceptions, microfinance institutions (MFIs), savings and credit cooperative organizations (SACCOs), and supermarkets were

[12] The distinction between wholesale traders and wholesale distributors is imprecise, but for the purposes of this investigation, wholesale traders are defined as shop owners that are located in the electronic goods markets in Nairobi who source products directly from manufactures to sell primarily on a wholesale basis. The majority of wholesale distributors are also located in Nairobi, with some notable exceptions located in Mombasa, and source products directly from manufacturers. However, wholesale distributors typically have formal contractual agreements with a small number of manufacturers and also participate in the marketing and distribution of those products to sub-distributors and retailers.

[13] Retailers include traditional brick-and-mortar shops as well as informal tables or sidewalk hawking. Retailers are generally stationary and located in urban or peri-urban contexts, whereas village-level entrepreneurs sell products at open-air markets, churches, and savings groups in rural areas.

[14] From May through July of 2014, M-KOPA transitioned from selling the d.light D20g, which was quality-verified, to selling the M-KOPA III, which is not currently listed on the website of quality-verified products.

not moving a substantial volume of product for the areas included in our surveys. However, there is uncertainty in these numbers because some managers were reluctant to disclose sales data during interviews.

Table 7: Six primary distribution channels in the off-grid lighting market.

Supply Chain Classification	Central Organizing Actor	Other Key Actors	Example
Non-Governmental Organization (NGO)	Non-profit social enterprise	Institutional partners, global manufacturers	SunnyMoney and Kenya public schools
Wholesale Distributors	Headquarter offices, global manufacturers	Institutional partners	SolaTaa
Wholesale Traders	Regional distributors and retail networks	A diverse set of retailers and resellers	Wholesale traders in Lithulu Avenue markets
Proprietary Channels	Global manufacturer or private company	Retail channel partners	d.light or M-KOPA
Franchise	Global retail chain owner	Global manufacturers	Total petrol stations
Microfinance	Microfinance institution (MFI) or Savings and Credit Cooperative Organizations (SACCO)	Global manufacturers, regional distributors	Rafiki, K-REP, or Unilever SACCO

It is important to note that, while the channels for distribution have not changed significantly in the off-grid lighting supply chain as it has evolved over the years, the types of products and the volume of sales through each channel continue to evolve as the market develops. In particular, Figure 9 captures the flow of three distinct product types in Kenya's off-grid lighting supply chain. First, there are some forty-seven different pico products available on the market that have been tested and have met the Lighting Global quality standards.[15] The second category captures all other off-grid lighting products, including dry-cell torches, grid-charged emergency lanterns, key chain lights, and even non-verified solar lanterns and solar home systems. The final category is actually a unique subset of unverified products: the counterfeit products that have proliferated as successful solar products gain enough popularity to merit mimicry.

[15] Please see http://www.lightingglobal.org/products for a current and comprehensive list of all Lighting Global quality-verified products. Not all forty-seven products are available in the Kenyan market.

CHAPTER 5: CREATING AND DELIVERING QUALITY

Quality assurance information plays a critical role in informing product design and investment before a product makes it to retail markets. This can include:

Product Development: QA information can reduce risk for the manufacturer by providing information related to customer needs and quality standards. This is especially true when consumer-oriented research is used to inform the standards setting process.

Investment: Investors also depend on accurate product quality and performance information to make lending decisions. Quality verification by a third-party testing organization like Lighting Global can reduce risk for investors that provide initial or working capital for pico-solar start-ups.

Performance Testing and Disclosure: Once the quality of a product has been verified, that information needs to be communicated to key market stakeholders and consumers. This can include the publication of test results as well as customized stakeholder engagement.

Regulation: Government regulators, customs officials, and inspectors also play critical roles in setting and enforcing government mandated quality standards. International harmonization through widespread adoption of standards established by organizations such as the International Electrotechnical Commission (IEC) make it easier for manufacturers to deliver affordable, high quality products to multiple markets.

Quality signals like warranties or branding are useful for distinguishing higher quality products that are already available to end-users, but the majority of the most

important decisions about product design, financing, and distribution are made long before a product makes it to market. Engagement with key market stakeholders —manufacturers, investors, government regulators, and distributors—is crucial for an effective QA framework because the decisions that are made at the top of the supply chain determine the flow of products, information, and finance through the rest of the supply chain (Bloomstein 2013). As the gatekeepers to the market, these stakeholders not only determine which products are ultimately available to end-users, they also influence how those products are priced, presented, and serviced.

5.1 Financing

Investors and donors often use information about product quality and performance when conducting due diligence to determine whether or not a company merits support. As a result, QA information can play a significant role in determining which companies and products receive support through working capital, consumer-level financing, or social impact investment.

Access to working capital for distributors, sub-distributors, and wholesalers has an impact on how much inventory can be purchased and stocked (Dahlberg 2012). Since pico-lighting is more expensive and takes longer to turn over than D-cell torches or kerosene,[16] sufficient working capital is important for maintaining a consistent in-country supply. Given that pico-solar manufacturers often require up-front payment for

[16] One distributor indicated that the minimum turnover time is six months: three months for transport from China, plus three months for in-country distribution and sale.

production and shipping, and, given an elastic demand that fluctuates according to seasonal income cycles, access to working capital is critical for ensuring a consistent market presence for pico-products. This is particularly true for firms that provide financing to consumers (see below), as low-income customer segments often require relatively long loan tenors.

Consumer-level financing can vastly improve product sales and penetration. Consumer-level financing is available in two distinct forms: pay-as-you-go (PAYG) arrangements where ICT-enabled payments are made in installments and consumer loans made by micro-finance institutions (MFI), savings and credit cooperative organizations (SACCO), or hire-purchase and check-off arrangements (Alstone el al. 2015, Banerjee and Duflo 2012). Consumer-level financing is particularly important for solar products like study lamps and solar home systems because the initial cost is often prohibitive for individuals and families with few resources.

Finally, impact investors and charitable donors are interested in product quality and salability, but they also want to ensure that the product will fulfill a particular social or environmental need. An excellent example of this is the study lamp form factor that now dominates the pico-solar market. While these small solar lamps are increasingly popular due to their low price points and flexible use as a torch or ambient light, their suitability as study lights for children doing homework also makes them popular with investors and donors. Although detailed measurements of social impact are beyond the scope of a QA program, pay-for-performance financing through social impact bonds or

carbon markets could provide an attractive source of funding for high quality products that can be effectively monitored and evaluated.

5.2 Distribution

Distributors, NGOs, and franchises also depend on QA information and exert significant influence on the types of products that are available in the market. Taking into account the ease with which supply-chain actors are able to source low-quality products from generic manufacturers and circumvent customs inspectors with bribes or intra-Africa importing, engaging with product distributors and traders is critical for supporting the availability and movement of quality-verified products in the supply chain (Duke et al. 2002). In this way, the distribution channels that carry counterfeit and unverified products in Figure 9 indicate where information about product quality and performance is most needed.

As an example, the fact that none of the wholesale traders that were interviewed in Nairobi had heard of Lighting Africa or seen one of the product specification sheets underscores where quality assurance information is severely lacking: the wholesale markets in the Luthuli Avenue, River Road, Nymakima, and Kamukunji sections of Nairobi where almost 40% of retailers in Kericho purchase lighting products and other wares. In the absence of such information, it is likely that the flow of low-quality and counterfeit products through these markets will continue unabated.[17] Connecting with

[17] Given that the quality of many counterfeit products is unknown, it is not clear what impact the availability of QA information would have on the prevalence of counterfeit products in the market.

wholesale traders is particularly challenging, though, as there are many more traders than distributors in Kenya, and many of these traders are insulated from the repercussions of selling low-quality products because of the limited availability of QA information in the market and the inability of buyers to seek recourse when they have purchased low quality goods. As one trader put it, "No one [here] cares about quality. They just care about money." Another source of reluctance is due to the fact that, unlike other consumer electronics like stereos, fans, rice cookers, or televisions, many traders think that the retail market in Nairobi for solar products is smaller due to grid availability (even accounting for consumers who purchase products for off-grid relatives). Be that as it may, quality-verified products and solar products in general represent an increasingly lucrative opportunity for the traders who sell to rural retailers, and the wholesale markets can also play an important role in facilitating comparison shopping within the supply chain.

5.3 Consequences of Quality

There are two additional challenges facing pico-solar systems in Kenya. First, quality solar lamps are consumer durables (long lasting products) that are forced to compete with cheap, fast-moving consumer goods (FMCGs)[18] like kerosene and dry-cell torches. Given capital constraints, most of the rural poor without electricity purchase domestic goods and energy services in small amounts at regular intervals. In Kenya,

[18] FMCGs are generally defined as products that can be purchased in small quantities at regular intervals to provide a temporary good or service (shampoo or laundry sachet, soap, soft drinks, food items, etc.). Consumer durables are defined as products that provide a service for at least two years (e.g. fan, mobile phone, radio, television, etc.) (Dibb et al. 2006).

kerosene can be purchased by the deciliter (~3.4 oz) to fill inexpensive wick or hurricane lamps. Cheap, dry-cell batteries can be replaced in low-cost torches and key chain lights, and candles provide the least expensive lighting service when the previous options are not available. While pico-powered lighting systems provide a superior lighting service from a renewable energy source, the up-front cost of this service is often greater than what most rural customers can afford. Ironically, the very characteristic that makes pico-solar more attractive—quality—also raises the initial cost and makes it less accessible.

As a result of their greater expense, consumer durables like pico-solar products tend to be sold in urban and peri-urban markets that are less accessible compared to village-level markets where FMCGs are sold. For example, FMCGs like candles and torches are readily available at small village general shops (dukas), enabling consumers to purchase what they want, when they need it without having to travel too far from home. In contrast, consumer durables are more expensive to transport and stock, and as a consequence they are less widely available. As a result, consumers are more apt to shop for consumer durables in urban or peri-urban markets where a greater number of shops offer more selection and better pricing (Neuwirth 2011).

While the distinction between consumer durables and FMCGs is less important for formal distribution channels such as NGOs, franchises, and proprietary supply networks, the impact on retailers is still significant. Almost 40% of the retailers in this study went to Nairobi to purchase their products. Many of these retailers purchase from the wholesale electronics markets where they can comparison shop, receive wholesale prices for small purchases, and pick up other FMCGs for their shops. In contrast,

sourcing solar lights from wholesale distributors is considerably less convenient. Wholesale distributor offices are often scattered around Nairobi instead of located in a central market, which results in greater travel costs for small business owners seeking inventory. Minimum orders to qualify for wholesale pricing or free transport are often prohibitive for smaller retailers. And the fact that most distributors carry only one line of products makes it difficult to provide greater variety to customers. In other words, another consequence of higher quality is that it can restrict the flow of pico-solar products to narrower distribution channels and limit the opportunities for comparison shopping.

5.4 Improving Retailer Distribution

Although Kenya has experienced unprecedented success in selling pico-solar products through institutional partnerships, these institutional sales are not considered a long-term solution. Sales through school campaigns can provide an effective stop-gap measure to accelerate the awareness and adoption of solar products in virgin markets, but they do not provide a reliable long-term distribution channel for sustaining sales or after-sales service.[19] With the greatest variety of products available and opportunities for connecting with customers, retailers figure centrally in strategies for reaching out to customers and communicating information about product quality and performance.

Given that retailers are the primary means by which end-users access lighting products, how does the average retailer decide which products to sell to his or her

[19] For example, SunnyMoney has developed a robust distribution network to continue sales after school campaigns. As of July, 2014, SunnyMoney was selling the d.light S2, S20, and S300; the Greenlight Planet SunKing Eco, SunKing Mobile, and SunKing Pro2; the Barefoot Connect 600 solar home system; and the Marathoner Beacon 290 solar home system through its distribution network.

customers?[20] Based on our interviews with retailers, there are at least five factors that figure into the customer's purchasing decision at the retail level: demand, durability, availability, access to finance, and affordability.

Demand and Durability: Sixty-three percent of the retailers that were interviewed learned about new lighting products from their supplier, while twenty-six percent found out from their customers (see Figure 10). In other words, before a retailer can purchase a new product, he or she must first be aware of and sense a demand for the product. But retailers also need information about the product quality, as nearly half of all customers focus on durability as a key characteristic when making purchasing decisions (see Figure 11). Retailers have an incentive to sell higher quality products in order to avoid customer complaints or dissatisfaction, and without other sources of information about product quality they often depend on personal experience, feedback from customers, and assurances from suppliers to decide which products to purchase.

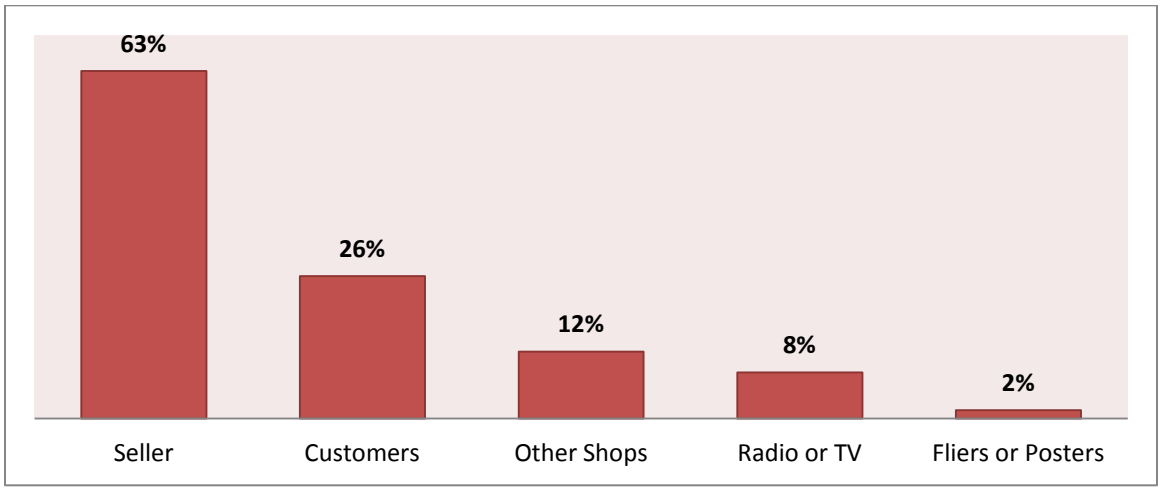

Figure 10: How retailers learn about new lighting products. Retailers could cite more than one source (N=132).

[20] Of all retailers interviewed for this study, 61% were male.

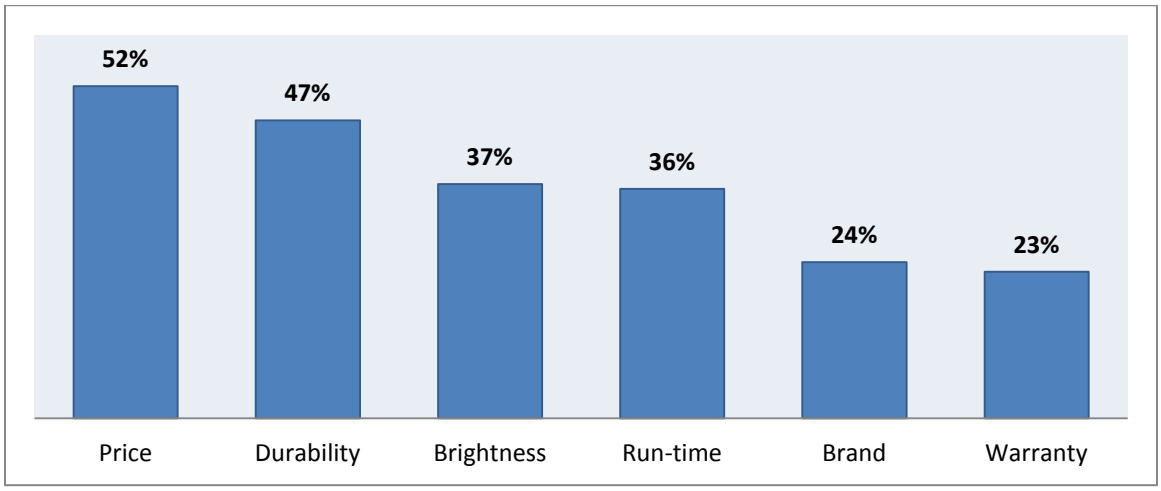

Figure 11: Percentage of retailers that reported receiving requests for particular product information when asked, "What information have customers asked for or used to make purchase decisions in the last week?" (N=132).

Availability: However, awareness and interest are not sufficient: retailers need reliable and consistent access to the product. If the product is delivered, is available from a local sub-distributor, or can be sourced from a trusted trader in Nairobi's wholesale market, then it is much more likely that retailers will be able to maintain consistent stock in their store. If the distributor is hard to find in Nairobi, the cost of shipping is too high, the minimum order for wholesale pricing is too high, deliveries are sporadic or unreliable, or the product selection is limited, then a retailer is less likely to try a new product or technology. From May to July when this research was conducted, many of our retailers commented extensively on their inability to fulfill consumer demand for d.light products due to the lack of available supply from d.light distributors.

Access to finance and affordability also play important roles in the retailer's purchasing decision. Torches and key chain lights are inexpensive, so it is easy to

maintain a steady stock and turn over inventory. Solar lamps are more expensive and sell less quickly, which means that the retailer must either have sufficient working capital to maintain stock or a consistent delivery mechanism for replenishing a small inventory. In some instances, the seller provides informal financing by giving the retailer a three- to fourteen-day grace period before payment is due. However, affordability is perhaps the most important criteria for retailers and customers (see Figure 11). Low quality products continue to thrive in the off-grid lighting supply chain because they are perceived to temporarily meet a need at a price that customers can afford. One reason for the success of study lamps, including quality-verified versions, is the fact that they are the least expensive solar lamp available.

In sum, QA information plays a critical role in influencing the flow of products, information, and finance at the top of the supply chain and determining which products are selected by vendors to sell to consumers. Given that vendors can choose between high quality, low quality, and counterfeit products, Lighting Africa has a strong incentive to continue engaging vendors throughout the supply chain to ensure that they are in a position to make informed decisions that ultimately benefit their businesses, their customers, and rest of the market.

CHAPTER 6: REDUCING UNCERTAINTY THROUGH INDIRECT SIGNALS

Once a product makes it to market, buyers still may not know how it will perform or how well it is suited to their needs. Absent this information, there are a variety of indirect signals like product presence, branding, or word-of-mouth referrals that can reduce uncertainty for the buyer and inform his or her purchasing decision.

6.1 A Dominant Presence

With over one million solar lamps sold in Kenya last year, pico-solar sales now represent a dominant share of the total sales revenue for off-grid lighting.[21] Although the selection of pico-solar products is still growing, 73% of the retailers interviewed in this study were selling a product powered by solar. In fact, of more than five hundred products recorded, 40% were powered by solar, more than any other energy source.[22]

The dramatic growth of the pico-solar market has two important implications. First, the marked increase of solar products in the market means that pico-solar is not only more available, it is more visible. Consumers like to purchase products that are aspirational—products that imply a higher standard of living, upward social mobility, or greater status and prestige—and customers with fewer resources are by no means the exception (Karamchandani et al. 2011). Therefore, the fact that solar products are stocked

[21] Based on reported pricing and sales volumes, quality-verified products represented roughly 50% of the total sales revenue, while all solar-powered products approximately 80% of the total sales revenue for the retailers interviewed in this study.

[22] Other categories noted were: 34% that were powered by dry-cell batteries, 31% with grid-charging capability, and 4% that were dynamo charged. With solar charging, the total numbers add up to more than 100% due to products that were powered by more than one energy source.

in more retail shops, supermarkets, and electronics stores—particularly stores in urban centers where demand is aggregated and consumers prefer to purchase consumer durables—lends to the credibility of solar technology.

Perhaps more importantly, as more solar products are sold, more customers are able to see first-hand how these products perform in their communities. This form of direct, eye-witness quality assurance cannot be understated because, as we will see, customers are most likely to purchase a product that they have already seen, experienced, or heard-about from a family member, neighbor, or other trusted source. When retailers were asked if the customers who purchased solar lamps came in looking for a specific product, 82% answered in the affirmative, indicating a dramatic increase in demand for solar products. In short, the increased visibility and availability of solar products in Kenya is one of the main means by which consumers are gaining more trust in solar technology more generally and in solar products more specifically.

6.2 The Emergence of Brand

One key observation made during the field study was that the d.light S2 has become one of the predominant products in the market. Representing almost a tenth of all products surveyed, the S2 was the most common product that was encountered.[23] Moreover, d.light was the most common brand that was seen in retail shops, representing 17% of all products. Greenlight Planet solar lamps (3.5%) and Tigerhead torches (3.1%)

[23] The closest runner-ups were the d.light S20 at 4% of all products and the d.light D20g sold by M-KOPA representing 2% of all products.

tied for a distant second. Several retailers indicated that they had begun to stock d.light S2 study lamps in response to customer questions and demands. In fact, two hardware stores that did not sell any other lighting products were selling d.light S2 lamps because customers had requested them.

In addition to the increased visibility and availability of d.light products, there was a broad identification of d.light as "the" solar light. Some retailers reported that customers used "d.light" and "solar" interchangeably, and one retailer said that a customer had asked for a "d.light eco."[24] However, it was clear that, despite the broad awareness of and demand for "d.light," customers and retailers were often referring to the S2 study lamp when they said, "d.light." In other words, while in some instances d.light was conflated with solar, in most instances d.light was most broadly identified with the S2 study lamp.

This conflation of manufacturer and model illustrates that consumer perception of products incorporates multiple layers of information, including official branding, form factor, and the context of availability. This could leave popular products like the S2 vulnerable to imposters that can adopt a subset of these signals. Two striking S2 counterfeits were encountered while conducting surveys, and one of them was nearly identical (see Figure 12).[25] Given that retailers and customers depend heavily on the

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[24] The SunKing Eco is a solar lamp that is manufactured by Greenlight Planet and sells at a price similar to the d.light S2. A customer asking for a "d.light eco" is akin to customers conflating "coke" and "soda" in some regions of the United States.

[25] The Winning Star TYN 355-372 had the exact same shape, wire stand, and even packaging as the d.light S2. Externally, the only differences were the brand name, the light-green rim around the enclosure, and a polycrystalline solar panel. (The original S2 solar panel was polycrystalline but has since been replaced with a monocrystalline panel.) It was also interesting to note that the Winning Star had a slightly larger battery than the S2.

shape and appearance of the product for identification, it was not surprising that several retailers were selling these products and the d.light S2 interchangeably. In fact, when one researcher returned to Kericho to try and locate several Winning Star samples for testing, almost no one knew what he was talking about when he asked for the Winning Star by name.

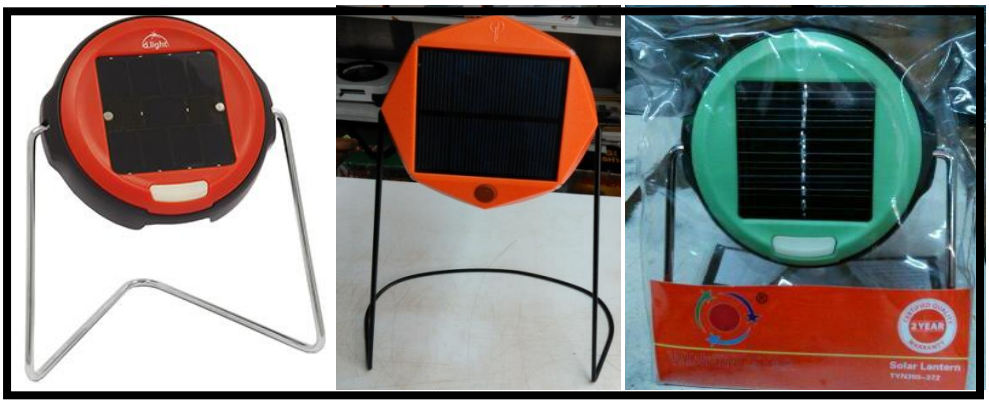


Figure 12: From left to right: a d.light S2, a counterfeit of the S2, and the Winning Star counterfeit of the S2.

While the growing demand for S2s indicates that consumer confidence in solar technologies is increasing, it is not clear whether customers are loyal to the brand or the form factor. In other words, the prevalence of S2 study lamps may have less to do with the emergence of the d.light brand and more to do with the way that the S2 has been promoted in the region. This may explain why brand ranked lower than durability, brightness, and even run-time when customers were deciding which product to purchase: even though most customers and retailers refer to the S2 as "d.light," they may not think of it as a brand (see Figure 11). Understanding the drivers of d.light's success has important implications for how products are promoted in other virgin markets. In

particular, when customers identify the product by form factor instead of by brand, the product is more vulnerable to counterfeiting and the ancillary benefits of brand-building (warranty servicing, product upgrading, after sales service, etc.) are diminished.

6.3 The Power of Referral

As mentioned earlier, SunnyMoney is selling more solar lamps than any other company in Africa. While an analysis of their sales strategy is beyond the scope of this investigation, it is important to highlight how the SunnyMoney model has contributed to the demand for the S2 study lamp in the Kericho area and the flow of information through the supply chain.[26]

In partnership with the Kenya Ministry of Education, SunnyMoney sells most of its study lamps through head-teachers in public schools. In rural areas with little previous exposure to solar products, head-teachers are recruited and trained to sell study lamps at their schools and in their communities. The efficacy of this model cannot be understated, as the head-teachers are an ideal medium through which to share information about solar study lamps. In talking with parents, students, savings groups, or church members, head-teachers explain the dangers associated with kerosene lighting, the durability and cost-effectiveness of solar lamps, the benefits of switching, and the utility of the lamp for

Figure 13: SunnyMoney logo.

[26] Please see "SolarAid: Revolutionizing the way to make energy affordable for everyone" by Howe, et al. (2012), for more information.

studying at home. With their education and training, head-teachers are generally perceived as a trustworthy source for information, and their high-standing in the community also lends to the credibility of what they share. Finally, although head-teachers often receive a financial incentive (commission) for selling lights, they do not depend on the income for their livelihood like local retailers or village-level entrepreneurs.

Given their commitment to children's education and their desire to keep the sale simple, SunnyMoney only promotes one study lamp in each school, and in the areas around Kericho they have almost exclusively promoted the d.light S2. Thus, the previous trends we observed—customers knowing which product they want when they enter the store, the greater availability of and demand for the S2, and the strong product-loyalty to the S2—may be due in large part to the innovative sales model employed by SunnyMoney. In a recent survey of fifty-eight SunnyMoney customers, participants knew an average of six people who had solar lights prior to their purchasing one. Eighty-five percent indicated that their purchase was influenced by a recommendation that they received, and 64% of participants stated that the recommendation of the teacher was the most important or main factor in their decision to purchase a solar lamp, more than their children (37%), friends or family (34%), or any other community leader (2%). In this way the success of the SunnyMoney model, which has made the d.light S2 a best-seller, involves a confluence of three critical factors: the recommendation of the teacher, the ability to see and experience the product directly in the community, and the critical mass of sales that animate interest and trust in the product.

Anecdotal evidence from interviews with retailers seems to support this hypothesis. Apparently in areas where SunnyMoney is promoting and selling the SunKing Eco, there are similar trends that are developing with consumer demand and form factor loyalty. Also, one sub-distributor indicated that neither the Eco nor the S2 seem to sell very well in areas where there haven't been any school promotions. In this way, indirect signals like product presence, branding, and word-of-mouth referrals can exert a significant influence on consumer behavior, particularly when applied in tandem. While an application of this sales model to other markets is beyond the scope of a QA program, it is worth underscoring how widespread institutional sales have positively impacted the rest of the market through increasing product visibility and consumer awareness. The SunnyMoney model in particular demonstrates how the quality of the signal—its source, whether it can be readily verified or experienced, and whether it appears to influence others in the community—ultimately determines its efficacy in influencing and informing consumer behavior.

CHAPTER 7: REDUCING UNCERTAINTY THROUGH DIRECT SIGNALS

While the indirect signals described above play significant roles in informing and influencing purchasing decisions, there are also direct signals like on-the-box labeling, advertising, and sales tools that can be used to promote products or facilitate comparison shopping. Thus far, the Lighting Africa QA program has been successful in engaging market stakeholders at the top of the supply chain, and this has had a positive impact on the rest of the market. However, there are still opportunities to engage traders, sub-distributors, retailers, and customers further down the supply chain to increase opportunities for comparison shopping and improve the overall flow of information about product quality and performance.

7.1 On-the-Box Reporting

On-the-box reporting is one of the most direct means of communicating information about product performance. In early 2015, Lighting Global collaborated with manufacturers to finalize reporting requirements for light output and product runtime. While the presentation of these performance characteristics will be left to the discretion of each manufacturer, these performance reporting requirements will play a key role in facilitating comparison shopping between similar products (see Figure 14).

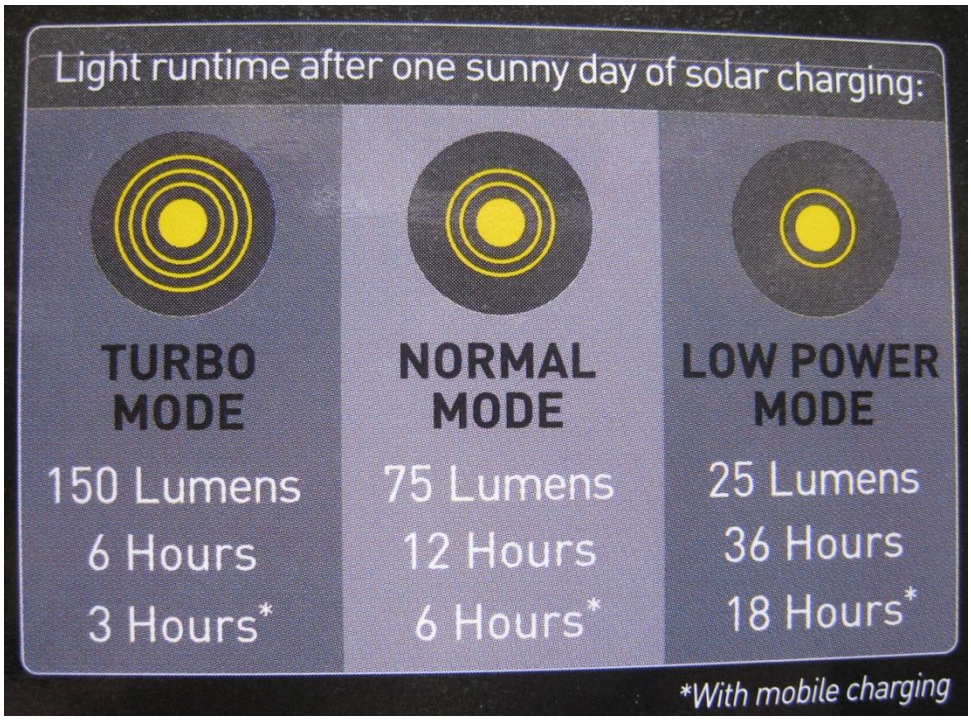


Figure 14: Example of on-the-box reporting for a pico-solar product.

7.2 Advertising and Promotion

Lighting Africa has worked hard to promote quality-verified solar products in Kenya through road shows, television advertisements, radio advertisements, and marketing materials like posters and fliers. When retailers were asked what they thought were the most effective ways of promoting solar products, 48% indicated that radio advertisements in the local language would be the most effective, followed by road shows (24%, see Figure 15), television advertisements (18%), and fliers (10%). With greater and greater penetration of radios and televisions into rural markets, it is likely that these mediums will become increasingly popular for promoting solar products.

Figure 15: Example of Lighting Africa road show in Kenya.

7.3 Tools for Promoting Solar

In each of our interviews with retailers who sold solar, four different promotional tools were presented, and retailers were asked which tool they thought would be most useful for learning more about solar technology, training employees, or selling more solar products to customers. The first was an example of a product specification sheet from the Lighting Global website. The second was a graphic representing a quality seal on the box of a solar product. The third was a printed excerpt from a flip book that describes solar

technology with pictures. The fourth was a picture of a YouTube video that would provide an audiovisual description of solar technology.[27]

As seen in Figure 16 and Figure 17, the specification sheets and flip books were overwhelmingly preferred by retailers, both as tools for internal knowledge building and as a means of selling more solar products to customers. Almost all of the retailers had never seen one of the Lighting Global specification sheets before, but they were particularly interested in the graphical header that displays the brightness and solar runtime for different settings and product features like mobile charging or additional light points. In one case a retailer reported being able to sell more SunKing Eco study lamps by showing customers that it was brighter and had a longer run-time than a similar lamp.

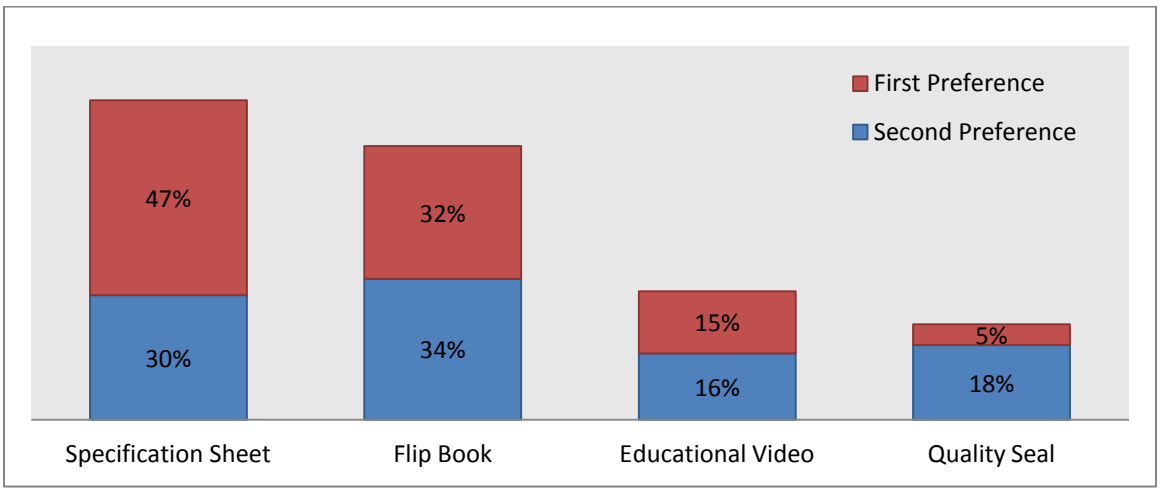


Figure 16: Retailer's most useful tools for learning about and training employees in solar technology (N=94). The first and second preferences represent the percentage of retailers that indicated that the particular tool would be their first or second preference.

[27] Please see Appendix B for examples of each tool.

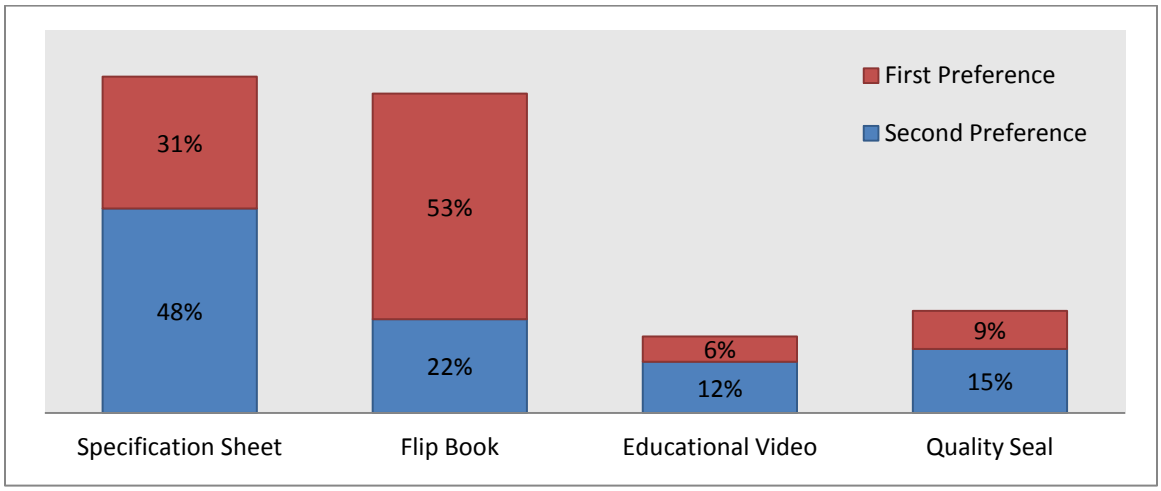


Figure 17: Retailer's most useful tools for selling more solar lamps to customers (N=94). The first and second preferences represent the percentage of retailers that indicated that the particular tool would be their first or second preference. The combined percentage represents the number of retailers that indicated the tool would be in their top two preferences.

Of course, while retailers figure prominently because they are closest to end-users, they are ultimately vulnerable to the decisions that are made further up the supply chain by distributors. During this investigation, semi-structured interviews with fourteen distributors in Kenya were also conducted, representing a variety of manufacturers and distribution channel strategies. Since the decisions of distributors affect the rest of the supply chain, their opinions about the tools described above were also deemed important (see Figure 18 and Figure 19). While the distributors represented a smaller sample size, they thought that the specification sheets and educational video would be most useful for training their sales staff, but that the flip book and quality seal would be most useful for selling more products to retailers and sub-distributors.

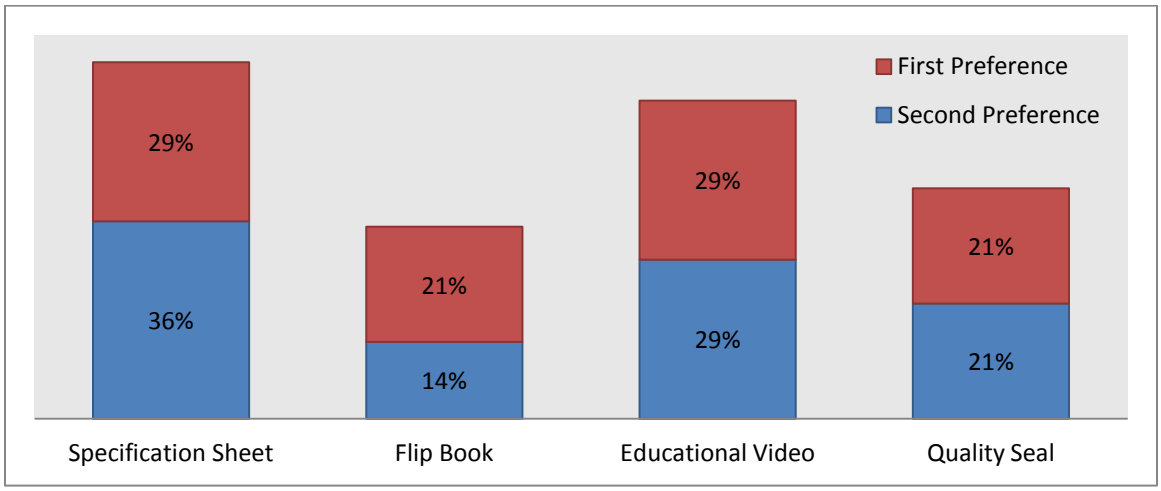


Figure 18: Distributor's most useful tools for learning about and training employees in solar technology (N=14). The first and second preferences represent the percentage of retailers that indicated that the particular tool would be their first or second preference. The combined percentage represents the number of retailers that indicated the tool would be in their top two preferences.

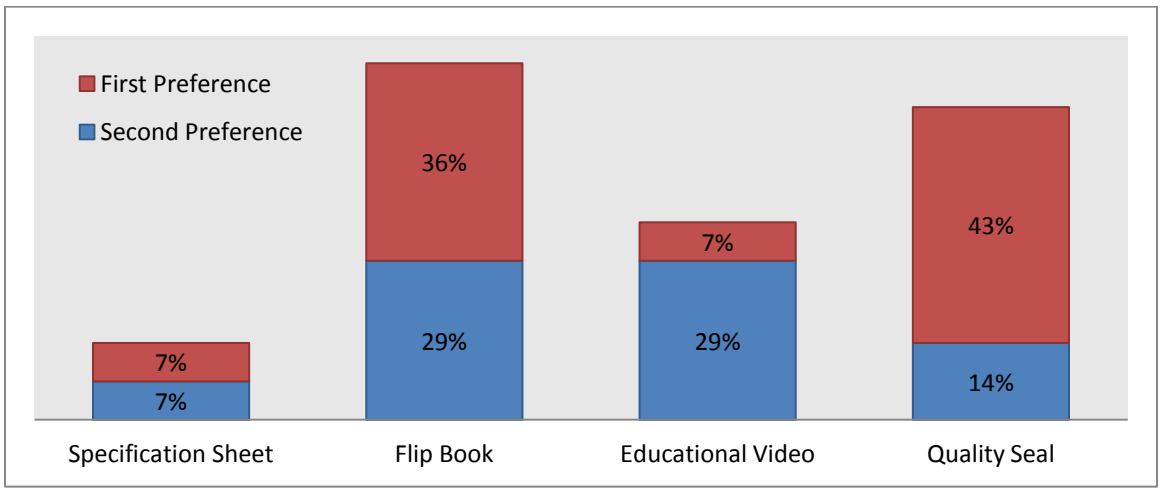


Figure 19: Distributor's most useful tools for selling more solar lamps to customers (N=14). The first and second preferences represent the percentage of retailers that indicated that the particular tool would be their first or second preference. The combined percentage represents the number of retailers that indicated the tool would be in their top two preferences.

As previously mentioned, Lighting Africa's quality assurance program has effectively engaged Kenya's solar distributors, so communication and information from Lighting Africa already played a significant role in the purchasing decisions for most of

the distributors that were interviewed. For example, two thirds had used the Lighting Global website to find out information related to product quality, and ten of the fourteen had already seen or used a specification sheet before.[28] In addition, five of the fourteen indicated that they used direct communication with the Lighting Africa team to access information related to the quality or performance of the products that they purchase.[29] Not surprisingly, ten of the fourteen indicated that they felt that it was easy to compare the quality and performance of different lighting products. When asked which mediums are most effective for communicating QA information to buyers, online publishing, on-the-box labeling, and radio advertisements were identified as the most effective mediums (Figure 20).

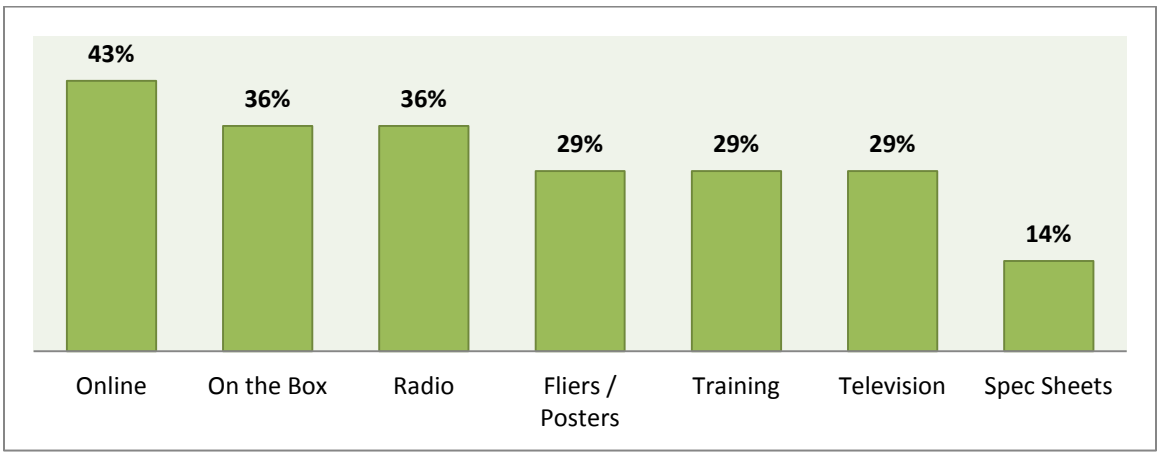


Figure 20: Distributor's most effective mediums for communicating information related to quality assurance. (N=14)

[28] Two had used it to compare competitors' products, one had used it to decide whether or not to make an order of product, and one had used it to convey information to his customers.
[29] Five indicated that they use feedback from customers, five indicated that they do internal testing, and six indicated that they use the internet to access information related to product quality and performance.

Finally, Figure 21 displays the information about product quality and performance that is most important to customers, retailers, and distributors. During our interviews with the retailers, they were asked what information customers ask about or use when they are purchasing products. The majority of retailers reported that price was the most important consideration for customers (52%), followed by durability and quality (47%), brightness (37%), and run-time (36%). Similarly, distributors were solicited for information that vendors ask about or use when they are purchasing products. In this case the most common concern was whether or not the product had a warranty (71%), followed by price (57%), durability and quality (36%), run-time (36%), and brightness (29%). When the distributors were asked what they considered the most important information about product quality or performance, the majority indicated durability and quality (43%), followed by the price, the warranty, and the run-time (21%). While it is interesting that brand was not mentioned explicitly by the distributors, this is probably due to the fact that most distributors deal exclusively with one manufacturer. It is also worth noting that distributors receive a lot more questions about warranties from retailers than retailers receive from customers. Besides these two anomalies, the responses from the different stakeholders were fairly congruent, with price, durability, run-time, warranties, and brightness figuring prominently in each stakeholder's purchasing decision.

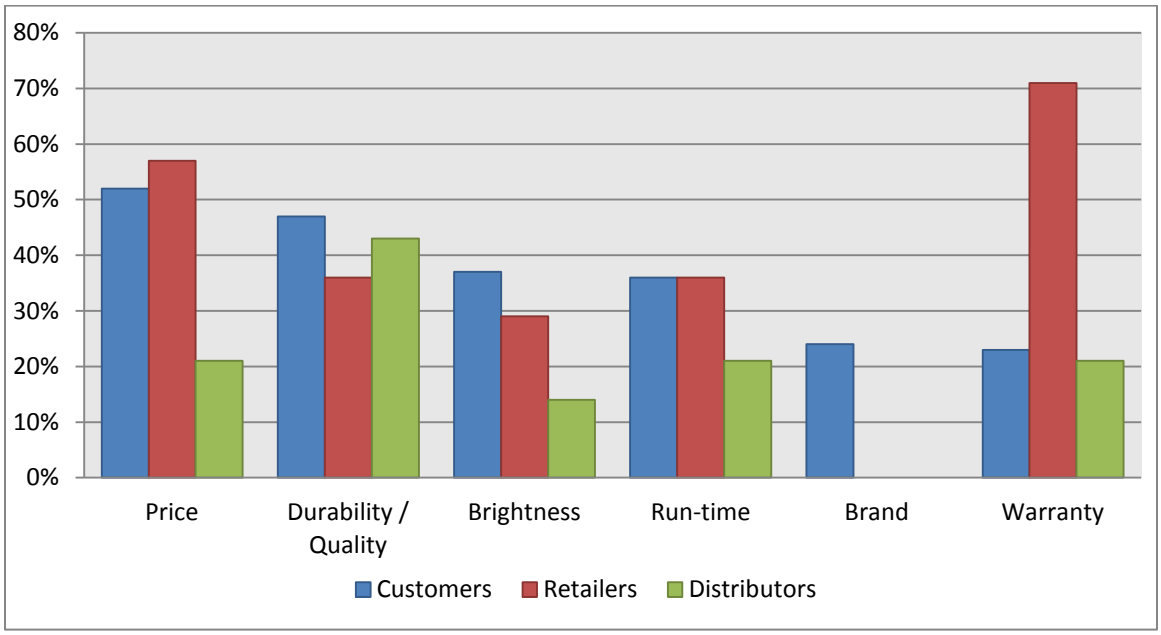


Figure 21: Most important product information for customers (N=132), retailers (N=14), and distributors (N=14). The customer preferences are as indicated by retailers, the retailer preferences are as indicated by distributors, and the distributor preferences are self-reported.

7.4 Digital Literacy and New Communication Channels

Another important finding from this investigation is that mobile handsets and services were widely utilized throughout the supply chain. As seen in Figure 22, the sophistication of mobile technology increased further up the supply chain, with the vast majority of pico-solar and solar home system (SHS) customers using basic phones, retailers having an even split between basic phones and smart phones, and the majority of distributors using smart phones.[30] The rapid penetration of smart phones and feature phones with social media applications could be particularly useful for increasing

[30] For the purposes of this investigation, smart phones were defined as mobile phones with touch screens or QWERTY keyboards and the ability to download and manage different applications; feature or internet phones were defined as mobile phones with access to the internet and fixed applications like Facebook, Twitter, or WhatsApp; basic phones referred to the least expensive phones with no internet access or applications.

connectivity throughout the off-grid lighting supply chain. As seen in Figure 23, both rural customers and retailers are increasingly comfortable with a variety of mobile services like text messaging, mobile money, and social media applications like Facebook and WhatsApp. The rapid rise of mobile coverage, access to mobile devices, and digital literacy in rural areas highlights the important role that information and communication technologies are playing in increasing connectivity, facilitating financing, and facilitating information flow in off-grid markets.

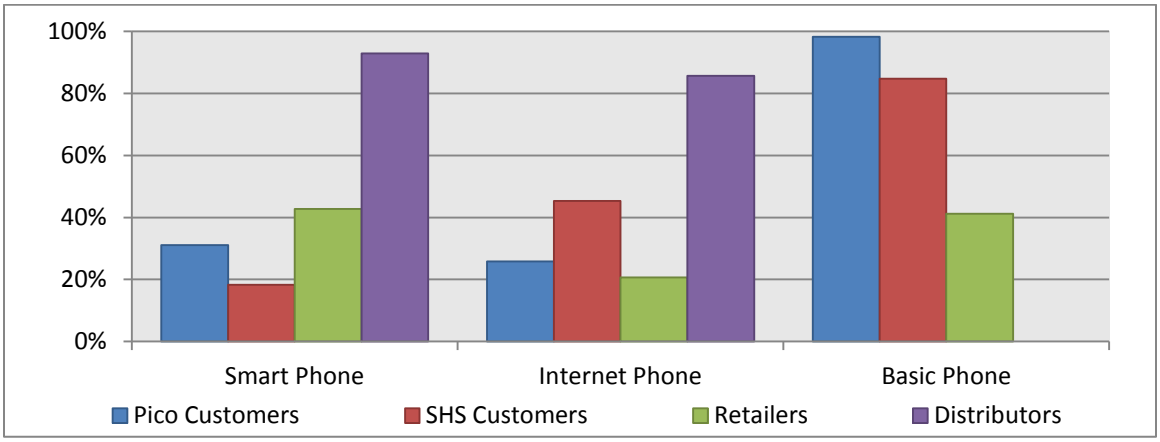


Figure 22: Types of phones used by pico-solar customers (N=58), SHS customers (N=170), retailers (N=130), and distributors (N=14).

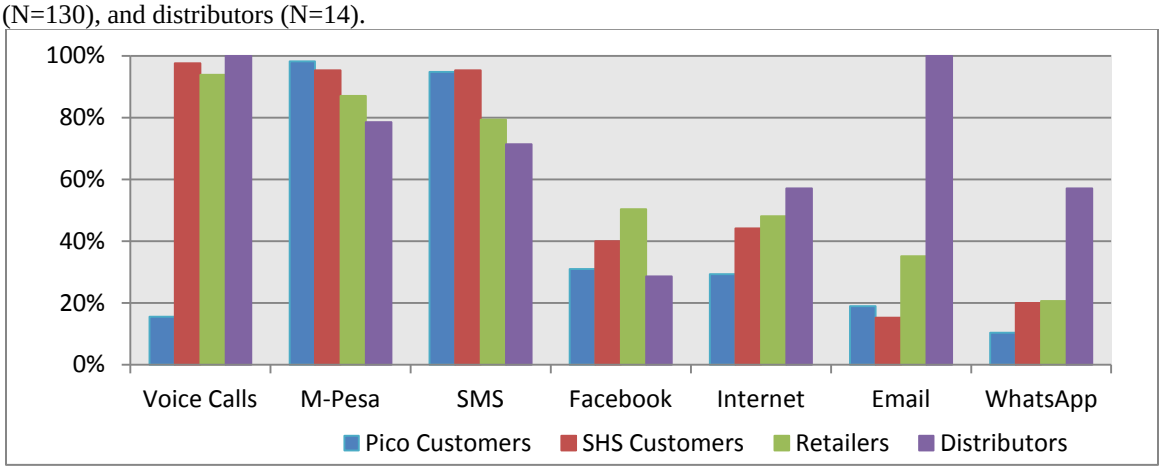


Figure 23: Mobile services frequently used by pico-solar customers (N=58), SHS customers (n=170), retailers (N=130) and distributors (N=14).

CHAPTER 8: REDUCING RISK THROUGH QUALITY SIGNALS

While direct and indirect signals can reduce uncertainty for buyers, they are not always reliable indicators of quality. For example, manufacturer advertising can increase consumer awareness and brand recognition, but that doesn't guarantee the product's quality. Similarly, a standardized format for reporting product run-time can improve comparison shopping, but it doesn't indicate how long the product will last. Quality signals like warranties, quality seals, and consumer financing play unique roles in reducing risk for buyers in the off-grid market. As such, their support and implementation merit particular consideration for the Lighting Global QA program and quality assurance programs more generally.

8.1 Quality Seals

The idea of creating a quality seal for products that meet the Lighting Global Quality Standards has been discussed at length within Lighting Global and with Lighting Global stakeholders. Western markets have provided a positive precedent for quality seals in the electronics and appliance industries, including both business-to-business (B2B) and business-to-customer (B2C) quality labels. Examples of B2B labels include the Underwriters Laboratory (UL) certification, the Conformité Européenne (CE) certification, and the external power supply quality label. Examples of B2C labels include Energy Star labels or the Eurovent Certification (see Figure 24).

Although these quality labels have been highly successful in OECD countries where there are protections against counterfeiting, it is not clear whether a B2B or B2C quality label would be as successful in an off-grid market like Kenya. In addition, effective marketing of a B2C label would require a substantial investment in promotion and advertising and strong partnerships with local regulatory agencies to ensure that practices conform to national regulations. Furthermore, implementing organizations may have to adapt B2C quality labels for local languages, which would be challenging in countries like Kenya where there are over 60 languages (Ethnologue 2014). Although a B2B label would still be vulnerable to counterfeiting, it would cost a lot less to promote the label among distributors, investors, and retailers in the supply chain and could have a positive impact on purchasing decisions. The possibility of investing in a B2C label could be contingent on the perceived success of a B2B label, its resilience against counterfeiting, and the availability of funding for marketing.

Figure 24: Different quality labels. Clockwise from top right: Conformité Européenne (B2B), Underwriters Laboratory (B2B), External power supply (B2B), Eurovent (B2C), Energy Star (B2C).

8.2 Warranties

Currently, products that meet the Lighting Global Quality Standards must offer and present a consumer-facing warranty. Warranties signal quality by providing a guarantee of repair or replacement in the event of malfunction during the warranty period (usually one or two years for pico-solar products). In theory, this guarantee holds manufacturers accountable for faulty products and also protects consumers from cheap products being dumped in the market. In practice, it is not always easy for customers to obtain after-sales service because not all retailers honor warranties, there is often an ill-defined process for assessing manufacturing defects versus customer misuse, and

determining the exact warranty period is also difficult.[31] Overall, it was found that only 8% of retailers offered warranties on all products, 38% offered warranties on products that had manufacturer warranties, and 54% of retailers did not honor any warranties. Given that only 20% of the products that were encountered in the market had known manufacturer warranties, it was encouraging to hear that, for 78% of products with manufacturer warranties, the retailer claimed that their business would honor the warranty.[32]

8.3 Consumer Financing

Similar to warranties, consumer financing can provide a quality signal for customers because the customer can stop paying if the product breaks or performs poorly during the payment period. Although this method for signaling quality is more abstract than a warranty or a quality seal, several of the customers that were part of our phone interview sample indicated that they thought a PAYG product would be higher quality than a similar product with an up-front payment. One customer that participated in our focus groups also indicated that customers "would like PAYG...because the customer has surety that it cannot be a fake product." One respondent thought that a PAYG product would be higher quality because the additional PAYG technology (e.g. keeping track of energy captured) indicates that it's an improved product. As this customer put it, "When

[31] Please see "Warranty Practices in Tanzania Retail Markets: Market Intelligence Note 4," for more information.

[32] There were sixteen of 130 retailers that indicated that they did not honor any warranties, even though they sold products with manufacturer warranties; those un-serviced products represented 22% of the products with manufacturer warranties that we saw in the market.

you pay in cash, you can't know what the quality of the product will be...PAYG wants to help you—it shows some concerns."

8.4 Perceptions of Quality

While customers may initially be wary of new products, brands, or technologies, over time these products, brands, and technologies can prove their durability and utility, thereby reducing uncertainty for customers trying to make informed purchasing decisions. Given the rapid growth of pico-solar products in Kenya's off-grid lighting market, it was not surprising that retailers thought that solar products in general were much more durable than grid-charged or dry-cell battery products. When the retailers were asked the expected lifespan of each of the lighting products available in their store, solar products had the longest expected lifespan on average (23 months) compared to grid-charge lanterns (6.2 months) and dry-cell battery torches (4.5 months, see Figure 25).

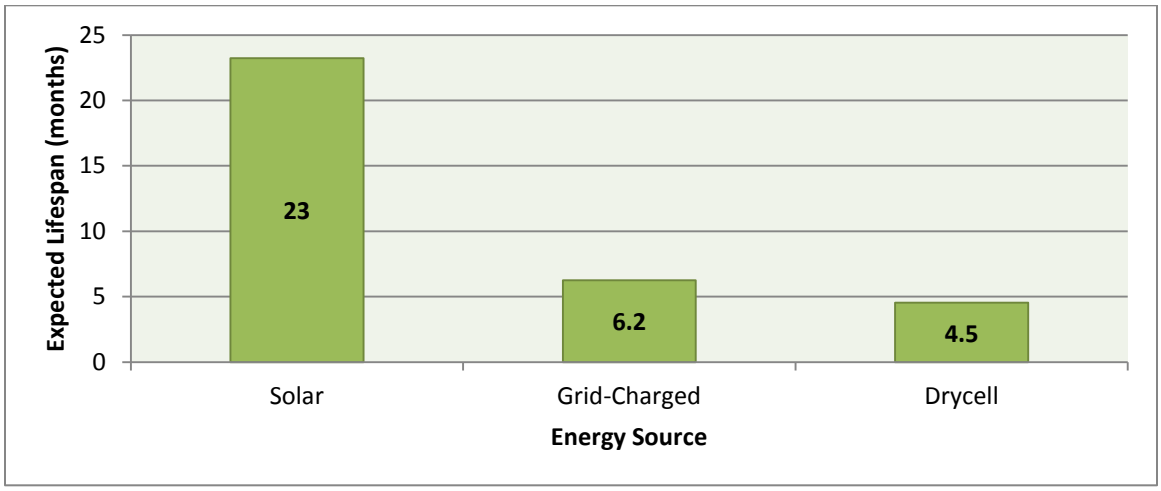


Figure 25: Expected lifespan for lighting products by energy source (N=473).

CHAPTER 9: CONCLUSIONS AND OPPORTUNITIES

There are a variety of ways that information about product quality and performance is accessed and shared in the off-grid lighting supply chain. The flow of information at the regional and global levels of the supply chain in particular plays a key role in determining how products are designed, whether or not they receive financing, how they are regulated or supported by institutional stakeholders, and ultimately whether they are purchased, promoted, and distributed by distributors. Further down the supply chain, there are indirect signals like market presence, brand recognition, and word-of-mount referrals that can help retailers and customers make informed purchasing decisions when comparison shopping is possible. There are also direct signals like on-the-box reporting, in-store sales tools, and advertising and promotion that simultaneously promote consumer awareness in the market while accelerating pico-solar sales. Finally, there are quality signals like product warranties, quality seals, and consumer financing that reduce risk for buyers by ensuring a minimum level of service life.

As demonstrated by the almost exclusive flow of quality-verified products through proprietary, wholesale distributor, franchise, and NGO distribution channels, Lighting Africa and Lighting Global have been highly successful at engaging market stakeholders further upstream in the off-grid lighting supply chain. With Lighting Africa activities beginning to transition to a second phase in Kenya and beginning to ramp up in other Sub-Saharan African countries, there are several opportunities for the Quality Assurance Program during the next phase of growth in the off-grid lighting market. This

final section addresses the types of content and mediums that Lighting Africa and Lighting Global could employ to improve the flow of quality assurance information throughout the off-grid lighting supply chain.

9.1 Communicating Quality Through the Supply Chain

In addition to engagement with key market stakeholders at the top of the supply chain, our team identified a variety of opportunities to improve access to QA information throughout the supply chain. As of 2014, mobile network coverage has increased to almost 96% of the population of Kenya, with 70% SIM penetration[33] and 11% of the population connected to the internet over 3G (GSMA 2015). The proliferation of mobile phones and services has contributed to dramatic increases in rural connectivity, digital literacy, and mobile-enabled banking and financing. Rapid penetration of smart phones into rural markets has also increased internet connectivity, enabling a whole host of web-based applications like email, Facebook, Twitter, and WhatsApp. Improved access to information and communication technologies (ICTs) combined with a rapid rise in digital literacy in rural markets has significant implications for Lighting Africa's quality assurance program.

[33] SIM penetration is a measure of the total SIM connections divided by the total population. Since some subscribers may have more than one SIM connection, it is not necessarily an accurate representation of unique mobile connections.

Opportunity #1: Use radio advertisements in the local language to promote quality-verified products. Retailers and distributors both indicated that this would be one of the most effective mediums for reaching new customers.

Opportunity #2: Create a simplified specification sheet that can be accessed easily on the Lighting Global website for each product and encourage manufacturers and distributors to reference and disseminate the simplified specification sheets when interacting with vendors. Also explore the publication of an illustrated flip book that explains how solar technology works, what the benefits are, how to maintain solar products, and how to service a warranty. These flip books could be shared with distributors to facilitate training and promotion higher up in the supply chain, and they could also be piloted among select retailers to test their impact on sales.

Opportunity #3: Make the Lighting Global and Lighting Africa websites compatible with smart phones, and particularly the product page. While a broader promotional campaign of the Lighting Global website would be required to substantially increase consumer visits, a mobile-friendly website and specification sheet would be an appropriate complement to verification letters, B2B quality labels, retailer specification sheets, flip books, or B2C quality seals. In a similar vein, Lighting Global could acquire lightingglobal.com and redirect it to lightingglobal.org in order to capture traffic from both domains.

Opportunity #4: Create a Lighting Global or Lighting Africa Facebook page. With 50% of retailers and 30% to 40% of customers using Facebook, a Facebook page could be an easy way to connect with stakeholders throughout the supply chain to provide updates on products, information on best-practices, or potential tips and tools for selling and promoting solar. Similarly, Lighting Global could consider exploring Twitter or WhatsApp as a means of connecting with distributors and retailers or facilitating referrals.

9.2 Signaling Quality to Buyers

Once a product is available in the market, there is also a need for quality signals that help inform customer purchasing decisions and facilitate comparison shopping.

Opportunity #5: Work with Lighting Global stakeholders to develop a B2B quality label to facilitate product entry and movement in the market. While customs and inspections vary from country to country, an on-the-box quality label could complement the verification letters that are currently used to demonstrate that a product has met the Lighting Global Quality Standards. In addition, a B2B quality label could be easily promoted among the distributors and sub-distributors already connected with Lighting Africa, potentially saving a lot of time and expense as products are updated or replaced with newer versions.

Opportunity #6: Depending on the success of the B2B quality label, its resilience against counterfeiting, and the availability of funding for marketing, consider promotion of a B2C quality seal for retailers and customers further down the supply chain

9.3 Improving Availability and Choices

Before a product can be sold to a customer, the vendor has to be aware of it, sense a demand for it, have reliable access to it, and be able to purchase sufficient inventory. Since most pico-solar products are competing with fast-moving consumer goods like kerosene, candles, and dry-cell battery torches, solar products will need to emulate the movement of FMCGs through the supply chain as much as possible in order to reliably reach rural customers.

Opportunity #7: Engage with wholesale traders in Nairobi. Based on conversations with Lighting Africa staff, there has already been discussion of performing a road show or consumer awareness campaign on Luthuli Avenue in Nairobi in order to connect with wholesale traders. Increasing the presence of solar products in the Nairobi markets could significantly improve comparison shopping for the retailers who travel from rural areas to purchase their electronic and household wares in the wholesalers markets. This is particularly important for smaller retailers who cannot purchase large orders, pay for shipping, or source solar products from the variety of distributors that are scattered in and around Nairobi. In this way, promoting pico-solar in Nairobi would not only increase the

desirability of pico-solar products; it would also increase their accessibility for pico-retailers.

Opportunity #8: Support financing and distribution strategies that enable good-quality pico-solar to compete with FMCG lighting products and increase opportunities for comparison shopping in the supply chain. This can include providing working capital for distributors and sub-distributors that have a hard time maintaining a consistent in-country inventory of products. It can also include facilitating financing for larger companies that have reliable payback rates but need additional capital in order to incorporate or expand PAYG financing.

Opportunity #9: Support strategies for consumer-level financing that help customers get over the initial-cost barrier and signal quality through extended payment periods. This can include researching best practices for PAYG financing, collaborating with micro-finance institutions (MFIs) and savings and credit cooperative organizations (SACCOs) to improve product selection, and exploring a wider array of mobile-enabled repayment methods. This could also include data sharing partnerships with PAYG providers for remote product quality testing, PAYG customer phone surveys, and broader market analysis.

9.4 Where to begin?

The previous nine opportunities represent distinct opportunities for the Lighting Global Quality Assurance Program to improve the accessibility of quality assurance information through the off-grid lighting supply chain in Kenya. However, given limited resources and budgetary constraints, it is useful to highlight the opportunities with potentials for broad impact and minimum expense. Based on interviews with stakeholders throughout the supply chain and consideration of the resources required for implementation in each case, it is recommended that the aforementioned opportunities be prioritized as follows:

1. Improve website accessibility (Opportunity #3)
2. Leverage social media platforms like Facebook to communicate with retailers and end-users further down the supply chain (Opportunity #4)
3. Create a simplified specification sheet and illustrated flip book (Opportunity #2)
4. Use radio advertisements in the local language (Opportunity #1)
5. Organize a road show on Luthuli Avenue to reach out to wholesale traders (Opportunity #7)
6. Implement a B2B quality seal (Opportunity #5)
7. Support financing and distribution strategies that improve access to pico-solar products (Opportunities #8 and #9)
8. Implement a B2C quality seal (Opportunity #6)

9.5 Opportunities for Further Investigation

The results from this study are by no means conclusive, and engagement with stakeholders throughout the off-grid lighting supply chain will have to adapt quickly as technologies develop, standards improve, user preferences shift, and markets evolve. In

particular, although retailers from four different markets were surveyed for this investigation, their responses were all lumped together in order to identify communication preferences for off-grid lighting retailers in general. Future studies could pay more attention to geographic considerations in the flow of quality assurance information through the supply chain and how stakeholder engagement might be customized between urban, peri-urban, and off-grid constituencies.

Similarly, many of the distributors that were interviewed during this investigation had already been contacted by the Lighting Africa team. Future investigations could try to tap into distribution networks for non-solar off-grid lighting products to see how quality assurance information could be shared with distributors who are not already convinced of the advantages of solar.

With over seven million quality-verified products sold in Africa as of 2014, the Lighting Global Quality Assurance Program has been able to support and participate in an exciting transition in global energy access for off-grid households. As pico-solar products becoming increasingly familiar, available, and affordable to end-users, the need to safeguard consumer interests with reliable QA information will only increase as the market rapidly and dynamically evolves. While Lighting Global prepares for the next iteration of growth in more mature markets like Kenya, hopefully the lessons learned will facilitate and accelerate the penetration of pico-solar products into new markets.

REFERENCES

Africa Electrification Initiative. (2012) "Institutional Approaches to Electrification: The Experience of Rural Energy Agencies / Rural Energy Funds in Sub-Saharan African." The International Bank for Reconstruction and Development. World Bank Group Website.

Akerlof, George. (1970) "The Market for Lemons: Quality Uncertainty and the Market Mechanism." *Quarterly Journal of Economics.*

Alstone, Peter, Dimitri Gershenson, Dan Kammen. (2015) "Decentralized energy systems for clean electricity access." *Nature Climate Change*, 5, 305-314. doi: 10.1038/nclimate2512

Alstone, Peter, Dimitri Gershenson, Nick Turman-Bryant, Dan Kammen, Arne Jacobson. (2015) "Off-Grid Power and Connectivity: Pay-as-you-go digital financing and supply chains for pico-solar." Lighting Africa Website.

Alstone, P., Lai, P., Mills, E. and Jacobson, A. (2014) "High Life Cycle Efficacy Explains Fast Energy Payback for Improved Off-Grid Lighting Systems." *Journal of Industrial Ecology.*

Banerjee, Sudeshna Ghosh; Bhatia, Mikul; Azuela, Gabriela Elizondo; Jaques, Ivan; Sarkar, Ashok; Portale, Elisa; Bushueva, Irina; Angelou, Nicolina; Inon, Javier Gustavo. (2013) Global tracking framework. Sustainable energy for all. Washington D.C.; The World Bank. http://documents.worldbank.org/curated/en/2013/05/17765643/global-tracking-framework-vol-3-3-main-report

Banerjee, Abhijit and Esther Duflo. (2012) *Poor Economics: A Radical Rethinking of the Way to Fight Global Poverty*. PublicAffairs.

Blumstein, Carl, and Margaret Taylor. (2013) "Rethinking the Energy Efficiency Gap: Producers, Intermediaries, and Innovation." Energy Institute at Haas Website.

Clark, Melissa, Joanna Melancon. (2013) "The Influence of Social Media Investment on Relational Outcomes: A Relationship Marketing Perspective." *International Journal of Marketing Studies*, Vol. 5, No. 4.

Cooper, T.E. (1992) "Signal facilitation: a policy response to asymmetric information." *Journal of Business 65*, pgs. 431-450.

(CIA) Central Intelligence Agency. (2009) World Fact Book. Available Online 25 February 2015: https://www.cia.gov/library/publications/the-world-factbook/geos/ke.html

Dahlberg Consulting. (2012) "Lighting Africa Market Trends Report." International Finance Corporation Website.

Daly, Aidan and Deirdre Moloney. (2004) "Managing Corporate Rebranding." *Irish Marketing Review*.

Dibb, S., Simkin, L., Pride, W. and Ferrell, O. (2006) *Marketing: Concepts and Strategies, 5th ed.* Houghton Mifflin, Boston, MA.

Division of Malaria Control, Ministry of Public Health and Sanitation, Kenya National Bureau of Statistics, ICF Macro. (2010) "Kenya Malaria Indicator Survey." Available Online 25 February 2015: http://dhsprogram.com/pubs/pdf/MIS7/MIS7.pdf.

Duke, Rick, Arne Jacobson, and Dan Kammen. (2002) "Product Quality in the Kenyan Solar Home Systems Market." *Energy Policy*, v30, pp. 477 -499.

Energy Sector Management Assistance Program. (2014) "A New Multi-Tier Approach to Measuring Energy Access." Sustainable Energy for All Website.

Ethnologue: Languages of the World. (2014) "Kenya." Available online at http://www.ethnologue.com/country/KE.

Greenwald, Bruce and Joseph Stiglitz. (1986) "Externalities in Economies with Imperfect Information and Incomplete Markets." *Quarterly Journal of Economics 90*, pgs. 229–264.

GSMA Intelligence. (2014) "Data > Markets > Africa > Kenya." GSMA Intelligence Website.

Harper, Meg and Arne Jacobson. (2013) "Warranty Practices in Tanzania Retail Markets: Market Intelligence Note 4." Lighting Africa Website.

Harper, Meg, Peter Alstone, and Arne Jacobson. (2013) "A Growing and Evolving Market for Off-Grid Lighting." Lighting Africa Website.

Howe, C., Lawrence, J., and Patel, H. (2012) "SolarAid: Revolutionizing the way to make energy affordable for everyone." Hult International Business School Publishing.

Hong, S. and R. Wyer. (1990) "Determinants of product evaulation: effects of the time interval between knowledge of a product's country of origin and information about its specific attributes." *Journal of Consumer Research 17*, pgs. 277-288.

International Energy Agency. (2010) "Energy Poverty - How to make modern energy access universal?" IEA Website.

Intergovernmental Panel on Climate Change (IPCC). (2014) Fifth Assessment Report.

Jacobson, Arne. (2014) "Quality Assurance for Off-Grid Lighting: Roadmap for Program Improvements." Presentation for Global Off-Grid Lighting Association.

Jacobson, Arne; Nicholas Lam; Tami C. Bond; Nathan Hultman. (2013) "Black Carbon and Kerosene Lighting: An Opportunity for Rapid Action on Climate Change and Clean Energy for Development." *Global Economy and Development at Brookings*.

Karamchandani, Ashish, Mike Kubzansky, and Nishant Lalwani. (2011) "Is the bottom of the pyramid really for you?" *Harvard Business Review.*

KNBS. (2005/06) "Kenya Integrated Household Budget Survey 2005-2006, Version 1.0 of the KNBS dataset." Kenya National Bureau of Statistics, Nairobi.

Lam, Nicholas L., Yanju Chen, Cheryl Weyant, Chandra Venkataraman, Pankaj Sadavarte, Michael A. Johnson, Kirk R. Smith, Benjamin T. Brem, Joseph Arineitwe, Justin E. Ellis, and Tami C. Bond. (2012) "Household Light Makes Global Heat: High Black Carbon Emissions From Kerosene Wick Lamps." *Environmental Science & Technology.*

Lay, J, J Ondraczek, J. Stoever. (2013) "Renewables in the energy transition: evidence on solar home systems and lighting-fuel choice in Kenya." *Energy Economics.* (40): pp. 350‑359.

Lee, Kenneth, Eric Brewer, Carson Christiano, Francis Meyo, Edward Miguel, Matthew Podolsky, Javier Rosa, Catherine Wolfram. "Barriers to Electrification for 'Under Grid' Households in Rural Kenya." National Bureau of Economic Research Working Paper Series. Available Online 27 April 2015: http://emiguel.econ.berkeley.edu/assets/miguel_research/57/Barriers_to_Electrification_for_Under_Grid_Households_in_Rural_Kenya.pdf

Leland, H. (1979) "Quacks, lemons, and licensing: A theory of minimum quality standards." *Journal of Political Economy 87*, pgs. 1328-46.

Lighting Africa. (2010) "Solar Lighting for the Base of the Pyramid: Overview of an Emerging Market." International Finance Corporation Website.

Lighting Global. (2014) "Lighting Global Quality Assurance Framework: Past, Present, and Future Support for the Off-Grid Energy Market." Lighting Global Website.

Lighting Global Website. (2015) Home page. Lighting Global Website.

Mills, Evan. (2003) "Technical and Economic Performance Analysis of Kerosene Lamps and Alternative Approaches to Illumination in Developing Countries." Lawrence Berkeley National Laboratory.

Mills, Evan. (2012) "Health Impacts of Fuel-Based Lighting." The Lumina Project Website.

Mills, Evan. (2014) "Light for Life: Identifying and Reducing the Health and Safety Impacts of Fuel-Based Lighting." United Nations Environment Programme Website.

Mills, Evan, Jennifer Tracy, Peter Alstone, Arne Jacobson, and Patrick Avato. (2014) "Low-cost LED flashlights and market spoiling in Kenya's off-grid lighting market." *Energy Efficiency*.

Ministry of Energy and Petroleum, Republic of Kenya. (2015) "National Energy and Petroleum Policy." Rural Electrification Authority Website.

Neuwirth, Benjamin. (2011) "Marketing Channel Strategies in Rural Emerging Markets." Kellogg School of Management. Available Online 22 November 2014: https://www.kellogg.northwestern.edu/~/media/Files/Research/CRTI/Marketing%20Channel%20Strategy%20in%20Rural%20Emerging%20Markets%20Ben%20Neuwirth.ashx.

Ondraczek, Janosch, Jana Stöver, Jann Lay, Arne Jacobson. (2012) "Household Lighting Fuel Costs in Kenya." *Lighting Africa Market Intelligence Note.*

Png, I.P. L. and D. Reitman. (1995) "Why are some products branded and others not?" *Journal of Law and Economics 38*, pgs. 207-224.

Ribot, Jesse and Nancy Peluso. (2003) “A Theory of Access.” *Rural Sociology*, v68, no2, pg. 153-181.

Spence, Michael. (2002) "Signaling in Retrospect and the Informational Structure of Markets." *The American Economic Review.* Vol. 92, No. 3 (Jun., 2002), pp. 434-459.

Stiglitz, Joseph. (1975) "The Theory of 'Screening,' Education, and the Distribution of Income." The American Economic Review, Vol. 65, No. 3, pgs. 283-300.

Tracy, Jennifer; Arne Jacobson. (2012) "The True Cost of Kerosene in Rural Africa." *Lighting Africa.*

Tedsen, Elizabeth. (2013) "Black Carbon Emissions from Kerosene Lamps: Potential for a new CCAC initiative." Ecologic Institute.

APPENDIX A: DISTRIBUTION CHANNELS OBSERVED

Table A.1 summarizes the different distribution channels that were observed during our field investigation from May to July of 2014.

Table A.1: Distribution channels observed in Kenya's off-grid lighting market.

Distribution Channel	Organization Observed
Institutional Partnership	SunnyMoney / SolarAid and Kenya Public Schools
Wholesale Distributors and Retailers	Distributors of pico-solar products (Nairobi)
	Retailers (Kericho, Brooke, and Talek)
	Last Mile or VLE Distributors
	Open Air Markets
Wholesale Traders (Nairobi)	River Road / Luthuli Avenue
	Nyamakima
Proprietary Channels	d.light
	SunTransfer (SunTransfer and Niwa)
	Barefoot
PAYG Companies	M-KOPA (d.light)
	Angaza (GLP)
	diviLite
	Azuri
Franchise	Total
NGO Partnerships	SunnyMoney / SolarAid
	Brighterlite (Fosera, Exide, BBoxx)
	One Acre Fund (GLP)
	Ecozoom (GLP)
MFI Partnerships	K-REP (Orb)
	Rafiki
	Faulu (Ecosmart)
	KWFT (Thrive)
	Simba Chai SACCO (Barefoot)

APPENDIX B: SOLAR SALES TOOLS

Figures B.1 through B.4 provide examples of the four tools that were used in our interviews with retailers to determine which tools would be most useful for training staff and selling more solar products to customers.

Quality Seal on the Box

Figure B.1: Representation of a quality seal on the box of a fictitious solar product.

Educational Flip Books / Flyers / Calendars

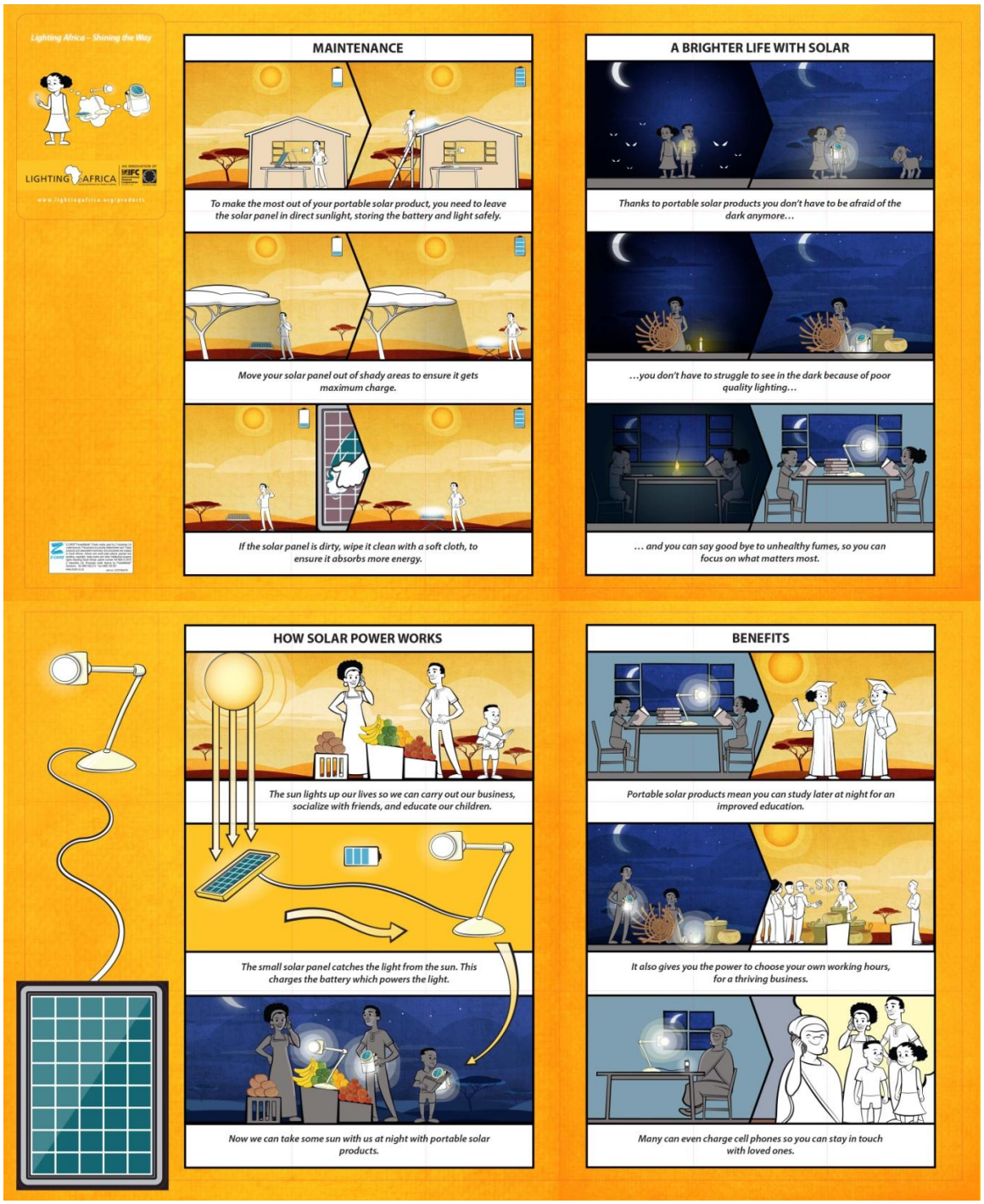


Figure B.2: Representation of pages from a flip book that illustrates the advantages of solar products, how solar technology works, and how to maintain solar products.

Internet Video

- What is solar lighting?
- How to buy it.
- How to use it.

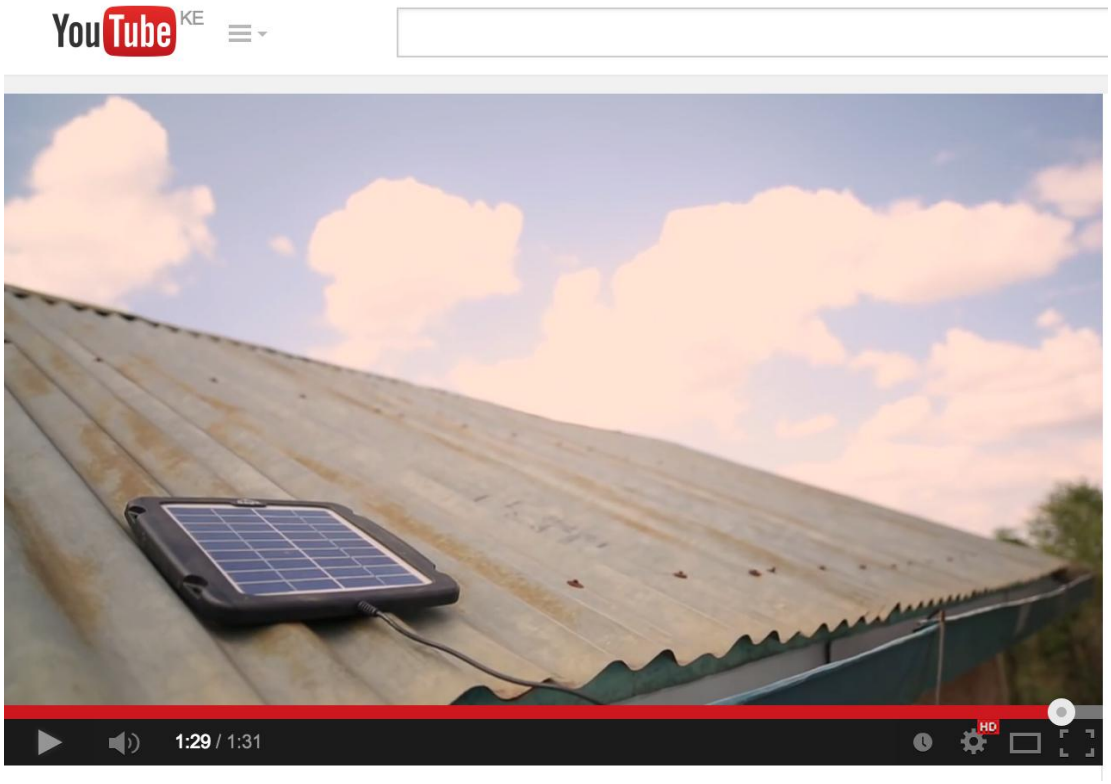


Figure B.3: Representation of a video that could be used to learn more about solar technology or to show to potential customers.

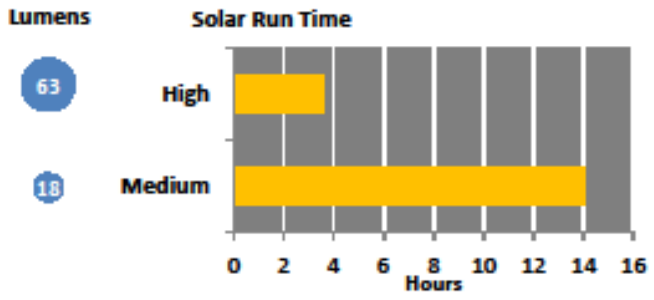
Firefly Mobile Lamp (Gen. 2.5)

Barefoot Power

Results based on test procedures detailed in IEC 62257-9-5, ed. 2.0

Verify Online: www.lightingglobal.org/products/bf-fireflymg25

Valid Until: July, 2014



Meets Lighting Global Minimum Quality Standards

Mobile Charging

1 **Light Point**

Warranty Information

A 1-year warranty for replacement of defective parts.

Performance Details

	Brightness Setting***	
Performance Measure	**High**	**Medium**
Full battery run time* (hours)	3.6	14
Run time per day of solar charging* (hours)	3.6	14
Total light output (lumens)	63	18
Total area with illumination > 25 lux** (m^2)	0.3	0.12
Total lighting service (lumen-hours / solar-day)	230	250

* Run time estimates do not account for mobile phone charging or other auxiliary loads; the run time is defined as the time until the output is 70% of the initial, stabilized output.

** Total area with illumination > 25 lux is determined by the maximum area with adequate illumination at a 0.75 m distance and at the distance from which the product would normally provide task lighting service.

*** Additional brightness settings (not tested): Low

Lighting Details

Lamp type	LED
Description of light points	Single unit on gooseneck with 10 LEDs
Colour characteristics	CRI 74 CCT "Cool" (5000-7000 K)
Distribution type	Wide
Lumen maintenance	100% of the original output remains after 2,000 hours run time

Figure B.4: Representation of a specification sheet that displays information about solar products that retailers could use in their shop.

APPENDIX C: EXAMPLE SURVEY

While there were several data collection efforts during this field investigation, the retailer surveys were most relevant to this thesis. All retailer surveys were conducted using the Open Data Kit application on tablet computers. However, the following questions and survey provide an example of the questions asked during the customer and retailer interviews.

Purchasing Motivation Questions:

How many people do you know who had solar lights before you bought one?			
Did anyone you trust recommend the solar light before your decision to buy one?	Yes, who? *(i.e. teacher, community leader, friend)*		No *(go to Q33)*
	Male	Female	
Was your purchase of the solar light influenced by these recommendations at all?	Yes		No

Please also rate how important each of these people were in your initial decision to buy the solar light	1 not at all important, 2 helped me decide, 3 considered equally with other factors, 4 was the main factor in my decision, 5 was the most important factor in my decision	1	2	3	4	5
	Teacher at the school					
	Friends/family with solar lights					
	My child telling me about the solar light					
	Community leader					
	Church leader					
	Other: *please write*					

offgrid-RETAIL-5-29-2014

Hello. We are talking to all the local retailers to gather information related to OFF-GRID LIGHTING PRODUCTS. We are using TABLET COMPUTERS today like this one to make it easier to collect the data.

Preparation

This interview is completely voluntary but if you have the time we very much appreciate you talking to us. Do you have ten minutes free?

- ◯ Yes
- ◯ No

Person conducting the interview:

- ☐ Maina
- ☐ Peter
- ☐ Dimitry
- ☐ Nick
- ☐ Mumbi
- ☐ Daniel
- ☐ Other

Specify other.

_____

Shop Info

Town:

- ◯ Kericho
- ◯ Wote
- ◯ Nairobi
- ◯ Machakos
- ◯ Brooke
- ◯ Talek
- ◯ Other

Specify other.

Type of shop:

- ☐ Electrical / Electronics
- ☐ General Shop
- ☐ Super Market
- ☐ Hardware
- ☐ Solar goods
- ☐ Kiosk
- ☐ Market Stall
- ☐ Table
- ☐ Hawker
- ☐ M-KOPA
- ☐ Sunny Money
- ☐ Total
- ☐ Other

Specify other.

What is the name of the shop?

How many employees work here?

Do you sell retail, wholesale, or both?
Select all that apply

- [ ] Retail
- [ ] Wholesale

Demographics

What is your name?
The person being interviewed

Gender:

- ( ) Male
- ( ) Female

What is your role at the shop?

- ( ) Owner
- ( ) Worker
- ( ) Other

Specify other.

What is your phone number?

Product types

What type of off-grid power / lighting products are available at the shop?
Read options and check all that apply

- [ ] Torches
- [ ] Array-type lighting (many LED's, not solar)
- [ ] Pico solar products
- [ ] Keychains
- [ ] Solar Home System Kits
- [ ] Solar Home System Components
- [ ] Battery backup powered lighting

Customer types

Are the typical customers for this product mostly men, mostly women, or about equal?

- ( ) Mostly Men
- ( ) Mostly Women
- ( ) Equal

Are the typical customers for this product mostly under 40, mostly over 40, or about equal?

- ( ) Mostly under 40
- ( ) Mostly over 40
- ( ) Equal

Information Priorities: Customers

What information have customers asked for or used to make purchase decisions in the last week?

DO NOT READ THIS LIST TO THE RESPONDENT. If they mention some of them, check off. If others, use other.

- ☐ Price
- ☐ Warranty terms / guarantee
- ☐ Quality label / mark
- ☐ Brightness
- ☐ The run time
- ☐ Mobile phone charging
- ☐ Durability
- ☐ Brand name
- ☐ Trust in the seller
- ☐ Powers a television
- ☐ Lighting Africa certification
- ☐ Other certification
- ☐ Not applicable / did not understand

Other things mentioned:

Information Tools: Information Source

Do you sell solar lanterns?

- ○ Yes
- ○ No

When customers purchase a solar product, do they come in looking for a specific product?

- ○ Yes
- ○ No

There are some new tools for selling solar products that are currently being developed. Which of the following things would be useful for you or your salespeople to learn about solar or choosing new products to sell?

Information Tools: Communication Tools

Specification Sheet

Show an example of a spec sheet to shopkeeper

- ◯ 1: Best
- ◯ 2
- ◯ 3
- ◯ 4: Worst
- ◯ Not useful

Quality Seal

Show an example of a quality seal

- ◯ 1: Best
- ◯ 2
- ◯ 3
- ◯ 4: Worst
- ◯ Not useful

Flip Book

Show an example of a flip book

- ◯ 1: Best
- ◯ 2
- ◯ 3
- ◯ 4: Worst
- ◯ Not useful

Educational video about solar lighting

Show an example of a video

- ◯ 1: Best
- ◯ 2
- ◯ 3
- ◯ 4: Worst
- ◯ Not useful

Are there any other materials that would be helpful for you or your salespeople to learn about solar?

Leave blank if they have no suggestions.

_____

Which of these things would be most useful to show to your customers in order to sell more solar products? 100

Information Tools: Communication Tools

Specification Sheet
Show an example of a spec sheet to shopkeeper

- ◯ 1: Best
- ◯ 2
- ◯ 3
- ◯ 4: Worst
- ◯ Not useful

Quality Seal
Show an example of a quality seal

- ◯ 1: Best
- ◯ 2
- ◯ 3
- ◯ 4: Worst
- ◯ Not useful

Flip Book
Show an example of a flip book

- ◯ 1: Best
- ◯ 2
- ◯ 3
- ◯ 4: Worst
- ◯ Not useful

Educational video about solar lighting
Show an example of a video

- ◯ 1: Best
- ◯ 2
- ◯ 3
- ◯ 4: Worst
- ◯ Not useful

Are there any other materials that would make it easier for you to sell solar products?
Leave blank if they have no suggestions.

Information Tools: Advertising Information

Which of the below options would be MOST USEFUL in getting more customers to purchase solar products?
Pick one

- ◯ Television Ads
- ◯ Radio Ads
- ◯ Road Show
- ◯ Fliers

Other things mentioned:

Supply chain information. The following questions refer to the supply chain for off-grid lighting products only.

Supply Chain

Do you buy from the same person / vendor or different ones?

- ◯ Usually the same sellers
- ◯ Usually different or multiple sellers
- ◯ I don't know / Can't say

What is the name of your primary distributor?

Where is your primary distributor located?
What town or city?

- ☐ Nairobi
- ☐ Nakuru
- ☐ Kericho
- ☐ Mombasa
- ☐ Abu Dhabi
- ☐ Other

Specify other.

How do you buy the products from the distributor?
Read options and check all that apply

- [ ] Go to buy
- [ ] They are delivered
- [ ] Other

Specify other.

How do you find out about new lighting products to sell?
Do not read options out loud

- [ ] The people I buy from
- [ ] I see other shops in town
- [ ] Customers ask for them
- [ ] Advertising on radio or television
- [ ] Local advertising / flyers / posters
- [ ] Other

Specify other.

ICT

» Introduction

Do you use a mobile phone?

- (●) Yes
- ( ) No

What kinds of things do you use the phone for?
Read options and check all that apply

- [ ] Voice calls
- [ ] Text messages / SMS
- [ ] Emails
- [ ] Internet
- [ ] Mobile Money (M-Pesa, etc.)
- [ ] Social Media (Twitter, Facebook, etc.)
- [ ] Other

Specify other.

» Mobile Stats

» » Mobile Information

How many mobile phones do you use?

What types of mobile phones do you use?
Read options and check all that apply

- [ ] Normal Phone
- [ ] Internet Phone
- [ ] Smart Phone

» » Mobile Credit

How much did you spend on phone credit yesterday?
Voice, data, and/or texting; Ksh per day

Is that a typical amount?
Phone Credit

- ◯ Yes
- ◯ No

What would be a typical amount?
Phone Credit

_____

» » Mobile Data

How many MB of mobile data did you use yesterday?
Number of MB

Is that a typical amount?
MB

- ◯ Yes
- ◯ No

What would be a typical amount?
MB

_____

» » Mobile Money

How many mobile money transactions did you make yesterday?
Like M-Pesa or other platforms

_____

Is that a typical amount?
M-Pesa transactions

- ◯ Yes
- ◯ No

What would be a typical amount?
M-Pesa transactions

_____

» Adoption

In what year did you get your first mobile phone?

In what year did you first start using mobile money (like M-Pesa)?

_____

» Internet

Do you ever use the internet to research lighting products?

- ◯ Yes
- ◯ No

Finance and Warranty

Do you offer guarantees or service warranties for customers?

- ◯ Yes, for all products
- ◯ Only for those manufacturers that support it
- ◯ No, not for any

Do you offer credit or financing to customers?

- ◯ Yes
- ◯ No

Do you access credit to run your business?

- ◯ Yes
- ◯ No

Where do you access credit for your business?
Check all that apply

- ☐ Bank
- ☐ Distributor
- ☐ Family or Friend
- ☐ SACCO
- ☐ Informal Loan (local loan agent)
- ☐ Other

Specify other.

_____

How do you use M-Pesa for your business (or other mobile money)?
Read options and check all that apply

- ☐ Customers can buy
- ☐ Pay a distributor / buy wholesale products
- ☐ I do not use it for buying or selling products.
- ☐ Other

Specify other.

_____

Datasheet

Has product information already been entered on a paper datasheet?

- ◯ Yes
- ◯ No

Product Information Section: Take a picture of the top three selling off-grid products by adding a new product information group for each one. *Top product first, second product second, etc.*
Product Information Section: Ask the shop keeper to show you the off-grid lighting products they have available and "Add a new Product Information Group" for each one.

Product Information

Form Factor

- ◯ Torch
- ◯ Study Lamp
- ◯ Ambient Lamp
- ◯ Solar Home System

Energy Source

- ☐ Dry cell battery
- ☐ Solar PV
- ☐ Grid-charging
- ☐ Dynamo

If it uses dry cell batteries, how many dry cell batteries does it use?

_____

Light Source

- ☐ LED
- ☐ Incandescant
- ☐ CFL

Quality marks / certifications on the package:

- ☐ KEBS
- ☐ CE
- ☐ ISO xxxxx
- ☐ UL
- ☐ TuV
- ☐ XX,000 hours lifetime
- ☐ none

Manufacturer Name

_____

Model Name

_____

Retail Price for one unit (Ksh)
Put the total price for all the units.

_____

Wholesale Price for multiple units (Ksh/x#)

_____

How many units for the wholesale price? (x#)
Write how many units are included for the given wholesale price.

_____

Does the sales person remember the split between retail and wholesale?
If no, do not need to enter detailed split below

- ○ Yes
- ○ No

How many of these did you sell last week? (# sold total)

_____

How many of those sales were retail sales?

_____

How long do you think this product will last?

Enter it in number of months.

If possible, please take a picture of the product

This is optional, of course

Please enter any notes about your observation

Please enter any comments here about TABLET surveys that were offered by the shop keeper.

GPS

Please record the location

GPS coordinates can only be collected when outside.

latitude (x.y °) longitude (x.y °) altitude (m) accuracy (m)

If not using internal GPS, enter location data here