Quality in the Off-Grid Solar Market

An Assessment of the Consumer Experience in Kenya

November 2021

eed ADVISORY

VeraSol


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Document title: Quality in the off-grid solar market: An assessment of the consumer experience in Kenya.

Submitted to: CLASP NGO

Acknowledgements

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The study was commissioned by CLASP and made possible by funding from World Bank/ESMAP, IFC and UKaid.

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WHAT GOD KNOWS
ABOUT ME IS
MORE IMPORTANT
THAN WHAT PEOPLE
SAY ABOUT ME

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Glossary of Terms

This study adopts the following definitions of commonly used terms within the solar industry that are yet to be universally defined.

- ***Component-Based Solar Systems:*** A solar energy kit whose individual components such as the solar module, battery, lights, inverter, wiring and appliances are sourced and assembled independently by either a product aggregator or an individual for their own household.
- ***Off-grid solar product:*** A stand-alone and autonomous solar powered unit or system that provides energy services including lighting and phone charging. These include solar lanterns, solar lighting systems and solar home systems.
- ***Off-grid solar appliance:*** An electrical device powered by solar that provides energy services other than lighting and phone charging. This includes solar fridges, solar water pumps, fans, televisions and radios.
- ***Off-grid counties:*** Counties that meet two criteria – (i) the prevalence of solar lighting products is above the national median reported in the 2019 Kenya Population and Housing Census, and (ii) the sales of solar televisions were above the average reported in Global LEAP Results-Based Financing sales data for Kenya.
- ***Quality-verified product (QV):*** An off-grid solar product that meets the requirements of the Lighting Global Quality Assurance testing and standards framework and is registered under the program.
- ***Non-quality verified product (non-QV):*** An off-grid solar product that does not meet the requirements of the Lighting Global Quality Assurance testing and standards framework or/and is not registered under the program.
- ***Affiliate brands (or affiliates):*** Manufacturers and distributors with at least one off-grid solar product of quality verified status.
- ***Non-affiliate brands (non-affiliates):*** Manufacturers and distributors with off-grid solar products of non-quality verified status.
- ***Solar Lantern:*** An off-grid solar product with one lighting point and a small solar panel either on the lantern as a unit or separately. The lantern may have a plug to charge a mobile phone.
- ***Solar Lighting System:*** An off-grid solar product comprising of a solar panel, multiple lighting points and a separate battery. The solar system is used for lighting and/or charging mobile phones only (no other appliance like radios etc) but unlike the solar lantern, there is more than one bulb.
- ***Solar Home System:*** An off-grid solar product comprising of a solar panel, a battery, multiple lighting points and appliances like televisions and radios. The solar panel is bigger than A4 in size.

List of Acronyms

EPRA	Energy and Petroleum Regulatory Authority
GEF	Global Environment Facility
GOGLA	Global Off-Grid Lighting Association
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
KEBS	Kenya Bureau of Standards
KEREA	Kenya Renewable Energy Association
KII	Key Information Interview
KNBS	Kenya National Bureau of Standards
KNES	Kenya National Electrification Strategy
KOSAP	Kenya Off-grid Solar Access Project
LED	Light Emitting Diode
LGQA	Lighting Global Quality Assurance Program
MoE	Ministry of Energy (Kenya)
Non-QV	Non-Quality Verified
OGS	Off-grid Solar
PAYGO	Pay-as-you-go
PVMTI	Photovoltaics Market Transformation Initiative
REREC	Rural Electrification and Renewable Energy Corporation
SHS	Solar Home System
SLS	Solar Lighting System
Solar	Solar
SWP	Solar Water Pump
QV	Quality Verified


sunshine

Executive Summary

THE OFF-GRID SOLAR ENERGY MARKET HAS GROWN INTO A US$ 1.75 BILLION GLOBAL INDUSTRY SERVICED BY OVER 1,000 COMPANIES AND ENABLING ENERGY ACCESS FOR 420 MILLION CONSUMERS.[1,2]

In sub-Saharan Africa, 5 million off-grid solar lighting solutions were sold in 2018, an increase of 3 million from 2016. East Africa accounted for approximately 50% of these new off-grid solar product consumers, with Kenya leading the market.[3] As of 2020, Kenya was approximated to have a 69% market penetration for off-grid products or about 6,000,000 live products.[4] The off-grid solar appliance market has also experienced growth. Globally, between 1.4 and 5 million off-grid solar televisions, fans and refrigerators were sold in 2019.[5]

The issue of quality assurance

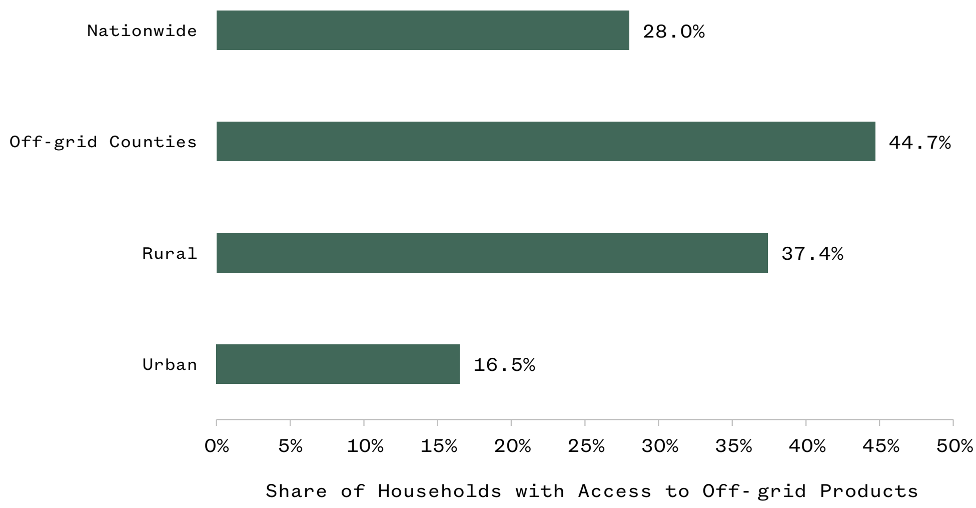
As the off-grid solar market has evolved and developed, quality assurance and specifically the ability of products to deliver expected services has been an area of concern. Studies have shown that lower quality products have infiltrated the market. For example, 71% of off-grid solar products of less than 10 Wp in the global market, referred to as pico-PV products, have not been verified for quality.[6] These types of products can be up to two or three times cheaper than similarly sized quality-verified products, but they are generally of lower quality.[7,8] A consequence of this trend may be a decline in consumer confidence and stagnation of the off-grid solar market.[9] In Kenya, 35% of pico-PV off-grid solar products sold in 2016[10] had been verified for quality, a proportion that increased to 50% by 2018.[11]

Lighting Global, an initiative of the International Finance Corporation and the World Bank, launched the first global quality assurance framework for off-grid solar products in 2009. This program is now being managed and expanded by VeraSol, an independent quality assurance facility established by Lighting Global, CLASP, and the Schatz Energy Research Center. Quality verification in the off-grid solar sector usually means products have been verified under the Lighting Global Quality Assurance framework (quality verified products), or not (non-quality verified products). The Lighting Global Quality Assurance framework provides a laboratory-based basis for quality assurance. However, there has been a gap in understanding how consumers perceive and experience the quality of off-grid solar products, and, as the market evolves, off-grid solar appliances.

A national survey of off-grid solar consumers in the Kenyan market

This study assesses the quality of off-grid solar products and appliances from a consumer perspective through a national survey. In total, 4,195 interviews were conducted across the 47 counties of Kenya to collect data on how consumers are interacting with quality verified and non-quality verified products in relation to price, durability, warranty and after-sales services. Analysis of survey results provided an overview of the Kenyan off-grid solar product market and characterization of the off-grid solar appliance market. It was found that 28% of Kenyan households (3,372,044 households) have access to at least one stand-alone off-grid solar product (Figure 1). Rural areas were found to access off-grid solar products at twice the rate (37%) of urban areas (16%). Of the 28% of households in Kenya with an off-grid solar product, three out of four (21.5% of all households) use an off-grid solar product as their main source of lighting. A particular set of counties, dubbed off-grid counties, were confirmed to have a higher prevalence of off-grid solar products compared to the rest of the country. In these counties, two out of every five households use an off-grid solar product as their main source of lighting.[12]

(ES) Figure 1: Household access to off-grid solar products per geographical strata



At the national level, almost 8 out of every 10 off-grid solar products reported were either solar lanterns or solar lighting systems. Solar home systems and component-based systems accounted for 14.0% and 6.9% of product types, respectively. Among rural households, 75.8% of the solar products were reported to be either solar lanterns or solar lighting systems, while 16.1% were solar home systems. In urban areas, 83.5% of households were found to use the grid as their main source of lighting compared to 43.5% of rural households. This is the likely reason why most solar products reported for urban households were for lower tier energy solutions such as backup lighting, portable lighting, and fixed room lighting. 88.2% of the products reported in urban areas were either solar lanterns (48.5%) or solar lighting systems (39.7%).

From the analysis, about 78.1% of the solar lanterns were identified as QV, while 81.0% of the solar lighting systems and 64.7% of the solar home systems were identified as QV. These prevalence rates for quality-verified products are higher than Pico market estimates reported in previous studies in 2016 and 2018.[13] The initial increase observed between 2016 and 2018 appears to have been driven by competition and quality, as the number of products available in the market dropped by 40%, with non-affiliate products squeezed out the most, indicating rising levels of consumer awareness about quality in Kenya.[14] The differences in the prevalence rate are likely due in part to continued market growth by affiliate which have access to more finance and well-established distribution channels. It is also noted from the survey, that there is a higher proportion of products breaking down for non-QV solar lanterns and solar home systems compared to QV systems, and this may also play a role in increasing the prevalence rate of QV products. Finally, this may signify a higher attrition rate of non-QV products which may not have been identified by the respondents during the survey. Targeted government programs like KOSAP, which deal with only quality-verified products, are also driving access to QV products.[15]

SOLAR HOME SYSTEMS AND COMPONENT-BASED SYSTEMS ACCOUNTED FOR 14.0% AND 6.9% OF PRODUCT TYPES

Kenyan consumers have adopted off-grid solar PV technology as an energy supply alternative

Common industry terms to describe off-grid solar products include solar lanterns, solar lighting systems, and solar home systems. Off-grid solar appliances are a growing category that includes radios, televisions, mobile phones, fridges, fans and water pumps, to name a few.

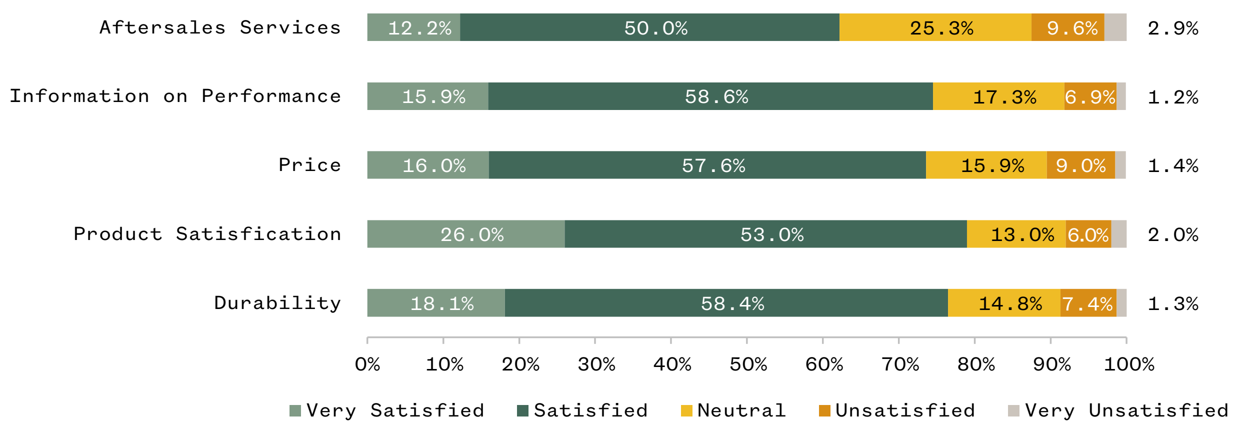
This study adopts these definitions with the exception that off-grid solar powered mobile phones were not assessed. The study found that off-grid solar products and appliances have been actively adopted in both grid-connected areas and areas not served by the grid. In urban areas with a grid connectivity rate of 84%, for example, 9% of households use off-grid solar products for their main source of back-up lighting during a power outage. Rural areas have a grid connectivity rate of 47%. This rate is close to the rate of off-grid solar product access in rural areas (37%).

Off-grid solar products deliver expected services

8 of every 10 survey respondents reported being satisfied or extremely satisfied with the quality of their off-grid solar product. Consumer perspectives on quality were assessed based on indicators of durability, pricing and after-sales service (Figure 2). Performance was defined as changes in the product's level of service including how often the product needed to be charged, how long it took to charge it, and whether lights were flickering or getting dim.

Only 12% of all respondents surveyed reported a breakdown of their off-grid solar product since purchase. Where products did breakdown, one in every two respondents associated the breakdown with the battery. Overall, respondents indicated they would recommend their off-grid solar product to relatives and friends.

(ES) Figure 2: Satisfaction levels for off-grid solar products across a range of metrics

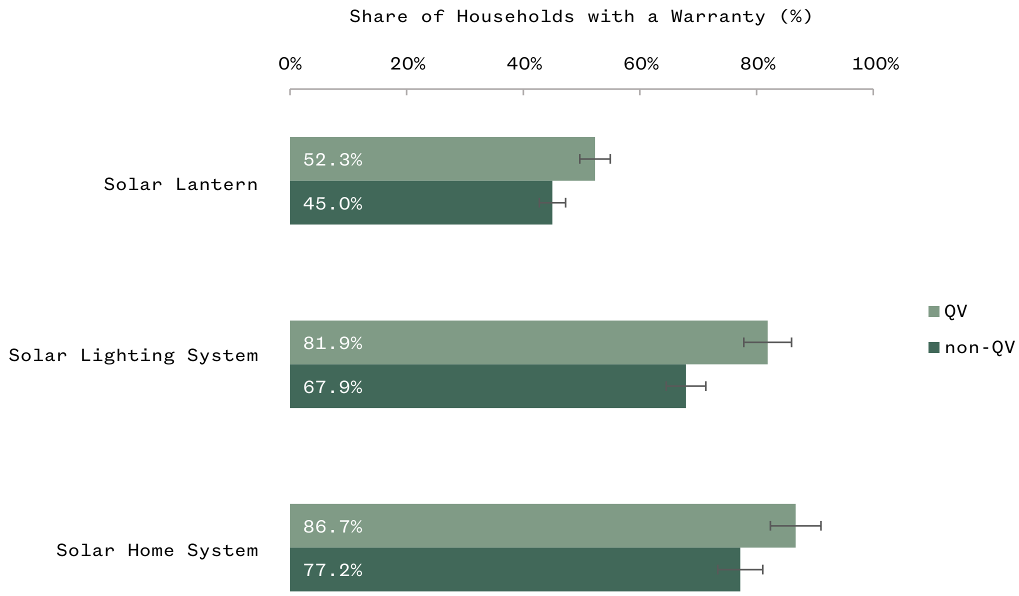


A clear link between quality assurance and consumer satisfaction in some, not all, aspects

This study found that it was not always clear how quality verification influenced the experience of consumers. Aspects where there were clear, statistically significant differences between quality verified and non-quality verified products were:

- Respondents with quality verified solar lighting systems reported a 77% rate of satisfaction with product durability, while those with non-quality verified systems reported a rate of 72%.[16]
- A significantly higher proportion of non-quality verified solar lanterns (19%) and solar home systems (31.3%) were reported to have broken down compared to quality verified ones (9.2% and 8.9%, respectively).[17] The study found that the cost of repair for owners of quality-verified lanterns was lower at KES 247 compared KES 813 for the owners of non-quality verified lanterns. The cost difference was statistically significant.[18] The cost of repair for quality-verified and non-quality verified solar lighting[19] and solar home systems[20] did not vary significantly.
- A significantly higher proportion of respondents who had purchased a quality verified off-grid solar product reported having received a warranty for solar lanterns[21] and solar lighting systems (Figure 3).[22]

(ES) Figure 3: Share of respondents with a warranty for quality verified (QV) and non-quality verified (non-QV) products



Most off-grid solar product breakdowns are associated with batteries

This study found that breakdown of off-grid solar products and appliances was most commonly associated with battery issues. When respondents were asked which component was associated with malfunctions, breakages or failures, close to one in every two respondents owning a solar lighting or solar home system identified the battery as the source of the problem. It appears that a focus on improving batteries, including the type, design, configuration and position in systems, will improve the overall performance of off-grid solar products. The next most common component associated with product breakdown was the switch.

Warranty and the cost of repair

This study found that the total amount used to repair or replace an off-grid solar product for consumers without a warranty is more than double that of consumers with a warranty. Solar lanterns were found to cost an average of KES 195 to repair with a warranty compared to KES 368 without a warranty. Solar lighting systems with a warranty cost an average of KES 440 to repair compared to KES 940 for systems without a warranty, while it costs owners of solar home systems without a warranty six times more (KES 4,768) to repair faulty systems compared to KES 769 for warranty holders. The cost of repair across the different product lines is tied to labour and replacing parts. Depending on the terms of individual warranties, distributors and manufacturers may cover labour costs and require the consumer to purchase parts.

Radios and televisions dominate the off-grid solar appliance sector

This study found that radios and televisions are overwhelmingly the most commonly purchased off-grid solar appliance. As a result,

THIS STUDY FOUND THAT THE TOTAL AMOUNT USED TO REPAIR OR REPLACE AN OFF-GRID SOLAR PRODUCT FOR CONSUMERS WITHOUT A WARRANTY IS MORE THAN DOUBLE THAT OF CONSUMERS WITH A WARRANTY.

we recommend unbundling the term off-grid solar appliances to enable better analysis of products with a lower market share. The study found that off-grid solar radios and televisions were popular in both urban and rural settings. 80% of all off-grid solar appliances assessed for this study were purchased after 2017. This surge in purchases is likely to be because of stronger distribution networks and the establishment of flexible payment options such as pay-as-you-go.

Actions to better incorporate quality assurance in the off-grid solar market

While confirming that quality verified off-grid solar products deliver expected services, this study also found that non-quality verified off-grid solar products achieve high positive ratings, although at lower levels than those reported by owners of quality verified products. Quality goes beyond the inherent design features and characteristics of a product and includes the services supporting the product. The study observes that certain brands have captured significant market share in various counties and continue to do so. The presence of these brands on the ground, their flexible payment options, after-sales support, distribution networks and marketing channels have contributed to quality being associated with their products. Brand names are intricately linked with the perception of quality, and they influence purchase decisions.

The Lighting Global Quality Assurance framework provides quality verification for individual off-grid solar products. This study found a distinction in quality when comparing affiliated brand off-grid solar products with non-affiliated ones, as well as when comparing quality verified off-grid solar products and non-quality verified. Brand is a strong predictor of quality. The distinction in quality starts at the firm level rather than at the product level. Firms have an inherent need to maintain minimum standards of quality for the purpose of gaining market entry and expanding market share. This study recommends the development of firm-level quality verification methods and standards to complement product level verification.

Where product-level verification continues to be the main focus, this study also recommends further analysis related to the development and promotion of a quality seal. The study found that consumers are largely unaware of the Lighting Global Quality Assurance framework, Lighting Global or VeraSol. Consumers are therefore not distinguishing off-grid solar products based on quality verification. To ensure quality products are distinguishable by consumers, this study recommends that VeraSol consider developing and promoting a language-agnostic seal that can be authenticated using a free text message service. Implementing a VeraSol seal would require considerable and sustained resources, but it could provide the missing link that enables off-grid solar consumers to associate a mark with quality verification.

01 Introduction

1.1 An overview of off-grid solar in Africa

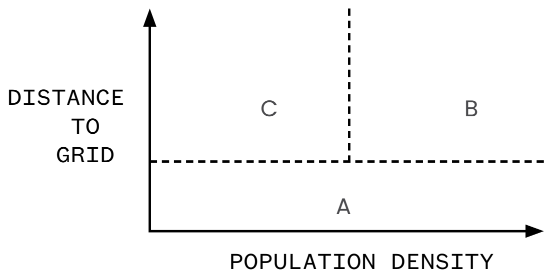
In the past, providing electricity to rural areas in Africa meant extending existing grids and increasing grid connections. The growth of the renewable energy sector, and in particular solar (solar), has significantly challenged this approach by offering energy solutions that do not depend on grid connectivity.

The off-grid solar market has been growing exponentially. 180 million off-grid solar products were sold globally in 2019 while in Africa analysis of one year, 2017, showed that 73 million households had gained improved access to electricity by adopting off-grid solar products over that period.[23,24] The drivers behind the growth of the off-grid solar sector have been the limiting costs of expanding existing grids to remote and sparsely populated areas, declining costs of solar technology, improvements to the regulatory environment, better mobile phone network coverage and the introduction of innovative business models such as pay-as-you-go.

The off-grid solar market has remained relatively active as the Covid-19 pandemic has affected markets worldwide. One affiliate, the global association for the off-grid solar energy industry or GOGLA, reported sales of 3 million off-grid solar lighting products between January and June 2020.[25]

Distance from the grid and population density can influence the choice of cost-effective and sustainable energy solutions. Figure 1 below shows that mini-grids can be viable for densely populated areas located far from the grid (B) while stand-alone systems may be the best choice for areas that are far from the grid but have few people (C). The International Energy Agency currently estimates that 26% and 31% of un-serviced areas in Africa are better suited to stand-alone systems and mini-grids respectively.[26]

Figure 1: Delineation of off-grid areas based on population density and distance from the grid.
Source: EED Advisory, 2021



1.2 The case for quality assurance: Introducing Lighting Global and VeraSol

Around the world, off-grid solar technology has developed faster than governance processes or frameworks to guide product quality. The demand for off-grid solar products and appliances has been high, but the lack of market frameworks has led to a proliferation of low cost and poor-quality products. This creates a risk that consumers may lose confidence in the sector. For example, a study by the Lumina Project on off-grid lighting adoption found that there was a statistically significant market spoilage impact on consumer willingness to buy high quality Light-Emitting Diode (LED) flashlights that was attributable to low quality LED flashlights. The study found that consumers who had been exposed to low quality lights were less likely to purchase LED lights regardless of quality.[27]

There is consensus among sector players that growth of the solar industry can only be maintained and even accelerated by adopting robust quality assurance processes. Two initiatives, Lighting Global and VeraSol, have and continue to play a key role in developing a quality assurance framework for the off-grid solar market. Lighting Global is an innovation of the International Finance Corporation and the World Bank. It was created in 2007 and in 2009 launched the first global quality assurance framework for off-grid solar products, the Lighting Global Quality Assurance framework. Lighting Global works with governments around the world to encourage the adoption of policies that lower market barriers and protect consumers.[28]

The Lighting Global Quality Assurance framework (at the beginning, Lighting Africa) provided testing standards for off-grid solar lighting products of less than 10 Wp (referred to as pico-PV products) and solar home system kits. In 2018, Lighting Global conducted laboratory testing of 17 non-quality-verified pico-PV solar products that were top sellers in Ethiopia, Kenya, Myanmar, Nigeria and Tanzania and found that all 17 products failed to meet the relevant standards.[29]

The off-grid solar market has continued to innovate and evolve beyond lighting products and into appliances and equipment such as televisions, refrigerators, fans and water pumps. This has created a need to develop quality processes for new and emerging products. In January 2020 VeraSol was established to offer an independent quality assurance program that builds on the strong foundations of the Lighting Global Quality Assurance framework while adapting to new technology. VeraSol has developed the technical foundations for assessing off-grid solar appliances and productive use equipment, and intends to expand quality assurance to these products in the near future.[30]

In addition to laboratory testing, there is a need to assess how off-grid solar products that meet the requirements of the Lighting Global Quality Assurance framework (quality-verified products) are being experienced by consumers. There is also a need to better understand how quality assurance influences consumer choices, and if verification of quality affects how consumers perceive affordability. A recent study by GOGLA and Hystra found that quality verified off-grid solar products can cost two to three times more than products that do not meet the requirements of the Lighting Global Quality Assurance framework (non-quality verified products) of similar solar module size. It is noted that the data used for that study was from distributors and manufacturers.[31]

1.3 The purpose of this study

Kenya has been a pioneer and world market leader in the uptake of off-grid solar pico-PV products. The Kenya National Bureau of Statistics 2019 population census found that close to one in four Kenyan households (24.5%) use an off-grid solar solution as their main source of lighting.[32] There is a wide range in the quality of these products, with Lighting Global estimating that low-quality products and counterfeits accounted for half of Kenya's Pico PV market (products with less than 10 Wp) in 2018.[33]

Several studies have been completed on the quality of off-grid solar products in the Kenyan market, but none have assessed the impact of quality verification from the consumers' perspective.

As quality assurance processes are developed and adopted to strengthen the off-grid solar market, knowledge is required on how consumers are interacting with quality verified and non-quality verified products in relation to price, durability, warranty and after-sales service. Knowledge is also required to better understand the fast growing off-grid solar appliances market.

VeraSol commissioned this study to:

i. Assess the state of quality verified and non-quality verified off-grid solar products in Kenya.

ii. Characterize the off-grid solar appliances market in Kenya at the household level.

The findings of this study will inform the activities of the Kenya Off-grid Solar Standards Steering Committee. The committee is a multi-agency platform with members from the Ministry of Energy, Kenya Bureau of Standards, the Energy and Petroleum Regulatory Authority, Strathmore Energy Research Centre, the University of Nairobi Lighting Lab, GOGLA and the Africa Clean Energy program.

CLOSE TO ONE IN FOUR KENYAN HOUSEHOLDS (24.5%) USE AN OFF-GRID SOLAR SOLUTION AS THEIR MAIN SOURCE OF LIGHTING

1.4 Study approach and objectives

Two focus areas have been defined for this study to represent the differences in product range and quality assurance between off-grid solar products and off-grid solar appliances (and equipment). These focus areas and their objectives are described as follows.

» **Focus area 1:** Off-grid solar products, namely off-grid solar lanterns, solar lighting systems and solar home systems. The study objectives for this focus area are to:

- Establish a baseline for quality verified and non-quality verified products.
- Evaluate the effectiveness of quality verified products and determine if these products deliver expected services to consumers.

» **Focus area 2:** Off-grid solar appliances, namely off-grid solar televisions, radios, fridges, fans and water pumps used at the household level. The study objectives for this focus area are to:

- Characterize the off-grid solar appliance market with regards to ownership, sales, affordability and penetration.
- Determine if consumers value product quality and how this affects consumer satisfaction.

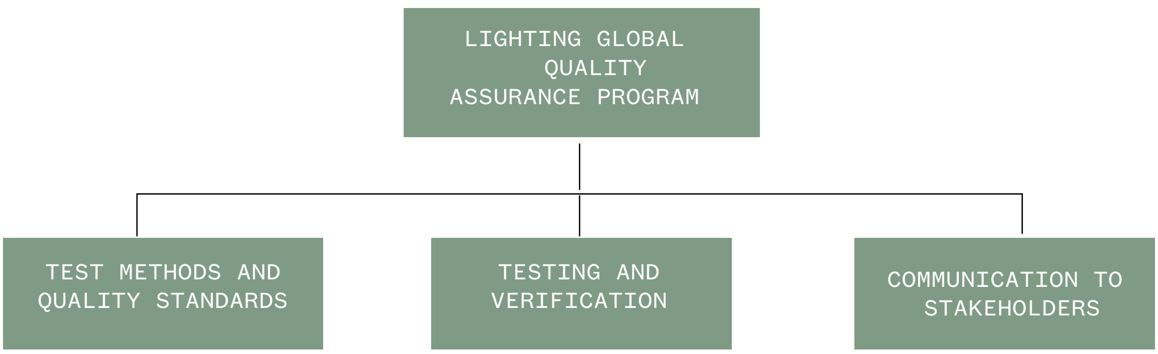
The approach used to meet these objectives was to develop and undertake a survey of Kenyan consumers and conduct an assessment at a national level stratified at urban versus rural level for each county. The methodology and results of this survey form the basis of this study and are detailed in following sections of this report. The survey collected data on the penetration of quality verified and non-quality verified off-grid solar products and appliances, consumer experiences and perspectives on quality and the drivers fuelling uptake of quality verified and non-quality verified off-grid solar products and appliances.

02 Quality standards

2.1 The Lighting Global Quality Assurance framework

The Lighting Global Quality Assurance framework launched by Lighting Global in 2009 provided the first universal basis for assessing the quality of off-grid solar products. The framework, which is now managed by VeraSol, provided a quality assurance program for solar lighting products and specifically for solar products of up to 10 Wp and solar home-kit systems. The three key components used to develop the framework were test methods and quality standards, testing and verification and communication with stakeholders. These components are illustrated in Figure 2. In April 2013 the testing methods developed under the Lighting Global Quality Assurance Framework were published by the International Electrotechnical Commission (IEC) as IEC TS 62257-9- 5:2013.[34] These methods have been revised twice since then. The most recent version of the methods are in IEC TS 62257-9-5:2018.[35]

Figure 2: Structure of the Lighting Global Quality Assurance framework.
Source: extracted from Lighting Global



The Lighting Global Quality Assurance framework distinguishes products as quality-verified or non-quality verified and sets minimum standards for quality, durability and truth in advertising as discussed in the following sections.

Pico-PV quality standards

The first standards that the Lighting Global Quality Assurance framework provided were for off-grid solar lighting products of less than 10 Wp. These standards, dubbed the pico-PV quality standards, evaluate the following aspects:

Truth in advertising: Accurate consumer-facing labelling.

Lumen maintenance: L90 time of greater than 2,000 hours.

Battery: Must be durable and adequately protected.

Health and safety: Batteries may not contain mercury or cadmium, products are safe.

Durability and quality: Appropriate protection to prevent early failure.

Warranty: Consumer-facing with at least one-year coverage.

Performance information: Run time and brightness reported along with a note about the impact of auxiliary appliance use, such as mobile phone charging.

Solar home system kits quality standards

Lighting Global expanded the initial pico-PV standards to include solar home system (SHS) kits of up to 350 Watts and below 35 V DC. These standards were named the SHS kits quality standards and they cover a similar scope of evaluation as the pico-PV quality standards, but with additional requirements. These requirements include a 2-year rather than 1-year warranty and more information for consumers in manuals to cover product components.

2.2 Accredited laboratories

Both the off-grid solar pico-PV quality standards and the solar home system kits quality standards require that:

- Samples from manufacturers are tested in accordance with the Quality Test Method (QTM) prescribed in the latest edition of International Electrotechnical Commission Technical Specification IEC/TS 62257-9-5.
- Testing is carried out at third-party laboratories accredited by VeraSol (previously Lighting Global) and that these laboratories meet International Organisation for Standards ISO 17025 standards.

Table 1 lists accredited laboratories, that is laboratories that meet the requirements described above, at the time of this publication.

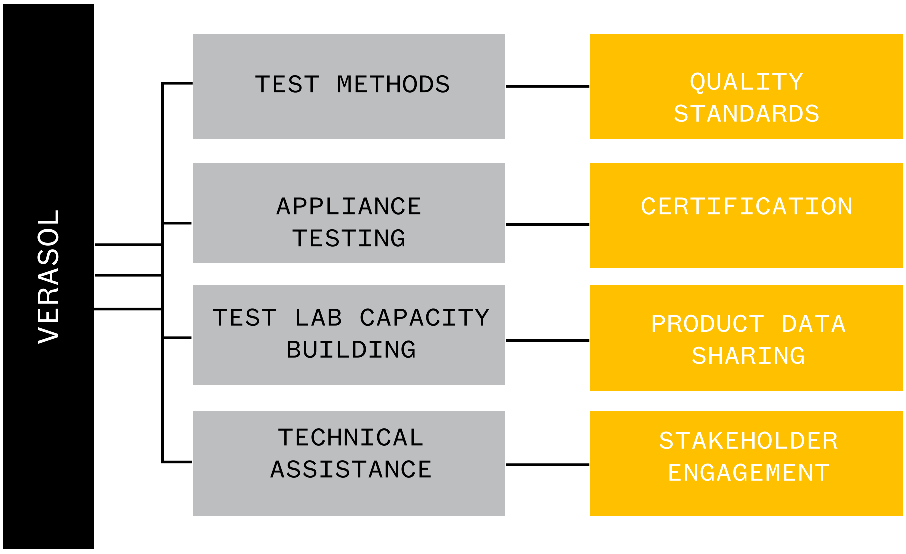
Table 1: List of accredited laboratories for testing solar energy kits [36]

NO.	TEST LAB AND LOCATION	APPROVED TESTS AND ROLES
1	Schatz Energy Research Center (SERC) Arcata, California, USA	Conduct Quality Test Methods, Renewal, Initial Screening Method, and Market Check Method tests for pico-solar products and SHS kits; Manage test lab network; Train new labs; and Coordinate development of test methods/updates to International Electrotechnical Commission specification
2	Shenzhen Academy of Metrology and Quality Inspection (SMQ), Shenzhen, China	Conduct Quality Test Methods, Renewal, and Initial Screening Methods tests for pico-solar products and Solar Home Systems kits
3	University of Nairobi Lighting Laboratory Nairobi, Kenya	Conduct Initial Screening Method and Market Check Method tests for pico-solar products
4	The Energy and Resources Institute (TERI) New Delhi, India	Conduct Initial Screening Method and Market Check Method tests for pico-solar products; Plan to conduct Quality Test Methods tests for pico-solar products
5	Intertek Hong Kong Hong Kong, China	Conducts Quality Test Method, Renewal, and Initial Screening Method tests for pico-solar products and solar home system kits

2.3 VeraSol quality assurance services and the Kenya Bureau of Standards

VeraSol has expanded the Lighting Global Quality Assurance framework to provide a wider range of services as described in Figure 3 below.

Figure 3: VeraSol Products and Services



VeraSol produces and keeps a database of verified off-grid solar pico-PV products, verified solar home system kits, tested off-grid solar appliances and tested off-grid solar productive use equipment. VeraSol is working to expand the current quality assurance framework to include quality standards for off-grid solar appliances and productive use equipment.

The Kenya Bureau of Standards (KEBS) has developed quality assurance measures for the off-grid solar sector that make use of international standards. In 2017 the bureau published mandatory quality standards KS 2542: 2017 for off-grid solar lighting kits of up to 10 Wp which complement the Lighting Global pico-PV quality standards.

In 2021 KEBS adopted International Electrotechnical Committee (IEC) Technical Specification (TS) IEC/TS 62257-9-5:2018 to replace IEC/TS 62257-9-5:2013.[37]

In addition, KEBS adopted IEC TS 62257-9-8:2020, which includes standards that apply to stand-alone renewable energy products including batteries and solar modules with direct current system voltages not exceeding 35V and peak power ratings not exceeding 350W. KEBS has expressed interest in continuing to domesticate relevant international standards in the off-grid solar sector including standards for component-based systems and balance of system components such as inverters.

03 The evolution of the OGS market in Kenya

3.1 Early investors and mid-term growth

Off-grid solar solutions emerged in Kenya in the early to mid-1980s at a time when regulatory frameworks and financial incentives for the renewable energy sector were yet to be developed. Early or first wave uptake of solar solutions were typically in the form of donor-led projects to provide lighting and borehole water pumping for institutions like schools and hospitals. Additional demand and uptake was likely constrained by the high price of solar technology. At the time a solar home system kit retailed for about 30 - 40 US$ per installed watt peak which meant that it could cost 900 - 1,200 US$ to power a basic 40 Wp system. Such a system could basically power a few light bulbs and a small black and white television.[38]

Technicians, suppliers and entrepreneurs could however see a viable market opportunity in providing alternative energy solutions in an environment with low national electrification rates and as the cost of solar technology continued to decline. This was especially the case in the solar powered batteries market, and companies such as Arco, Helios, BP Shell, Siemens, Solarex, Chloride Exide, Energy Alternatives Africa, Electrowatts and Associated Battery Manufacturers were some of the early players in this sector.

A second and more consistent wave of uptake of off-grid solar products in Kenya began in the late 1990s and continued through to 2014. Key drivers of growth during this period were:

- The launch of a multi-million-dollar solar markets transformation initiative by the International Finance Corporation in partnership with the Global Environment Facility to provide working capital and end-user finance for small-scale enterprises beginning with Kenya, India, and Morocco.[39]

- The emergence and rapid penetration of mobile phones in the early 2000s and the development of mobile money payment platform M-Pesa by Kenyan corporation Safaricom in 2007. M-Pesa enabled the development of the pay-as-you-go business model.

- The declining costs of solar technology, increased awareness of the impacts of fossil fuel use on climate and improvements in energy efficiency across electrical appliances and lighting products.

- The establishment of the Kenya Renewable Energy Association (KEREA) in August 2002 by the Kenya Bureau of Standards to develop standards for the off-grid solar sector. KEREA formalized what was previously a working group on renewable energy, the Renewable Energy Resources Technical Committee.

- The launch of the ground-breaking Lighting Africa program in 2009[40] to "*leverage new LED lighting technologies to build sustainable markets that provide safe, affordable, and modern off-grid lighting to communities in Africa that lack access to electricity.*"

3.2 The current market

By the end of 2012 the penetration of off-grid solar products in Kenya had crossed the one million mark.[41] The recognition of off-grid solar as a part of a national electrification strategy by the Kenyan government marked the start of a third and present wave of uptake. In 2014, the Kenyan government drafted an energy policy that sought to increase the electrification rate in the country to 65% by 2020 and attain universal electrification by 2030.

The means to achieve this were defined as expanding generation and distribution infrastructure, grid densification and deploying innovative decentralized solutions.[42]

In 2018 the Kenya National Electrification Strategy was developed which aimed to connect 269,000 households through grid expansion, 2.8 million households through grid intensification, 34,700 households through mini-grids and 1.9 million households through solar home systems.[43] This strategy incorporated off-grid solar into the country's energy strategy, and in support of this measure the World Bank launched the Kenya Off-grid Solar Access Project (KOSAP) in 2019.

Figure 4 and Figure 5 summarize off-grid solar adoption in Kenya and point to the continued present fast pace of growth. It is estimated that over 3 million off-grid solar products are currently in use in Kenyan households.[44] Solar technology has become more affordable. The Energy and Petroleum Regulatory Authority estimates that the price of this technology has dropped from KES 7,600/Wp in 1977 to KES 30/Wp at present.[45]

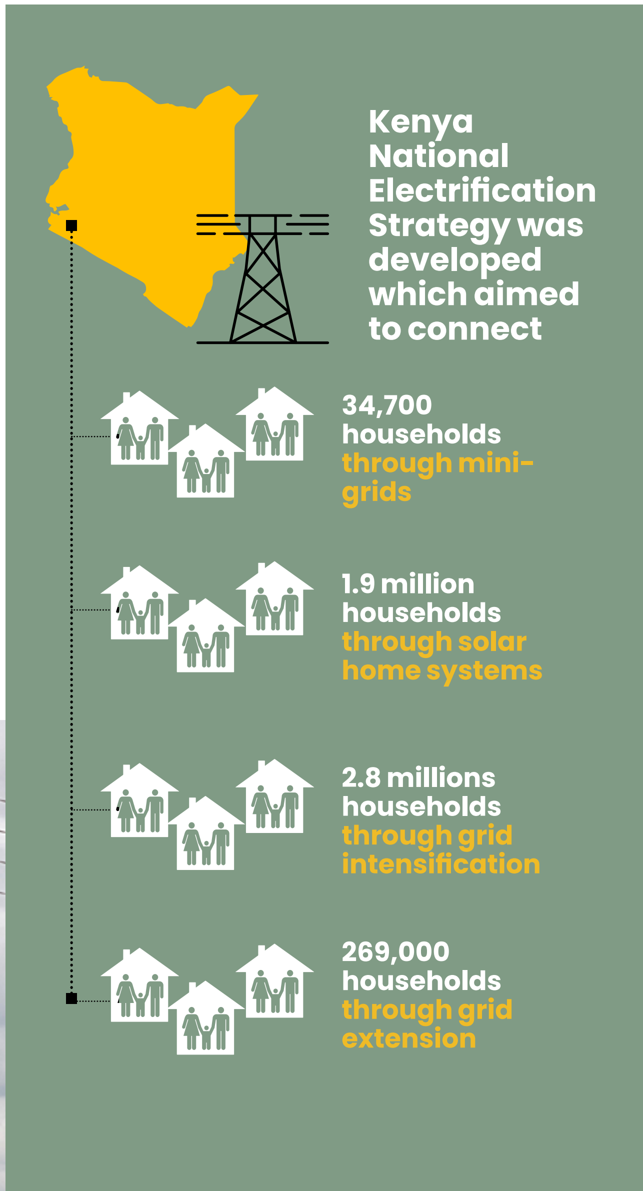


Figure 4: A timeline of off-grid solar adoption in Kenya.
Source: Compiled by EED Advisory with data from the World Bank Energy Sector Management Assistance Programme

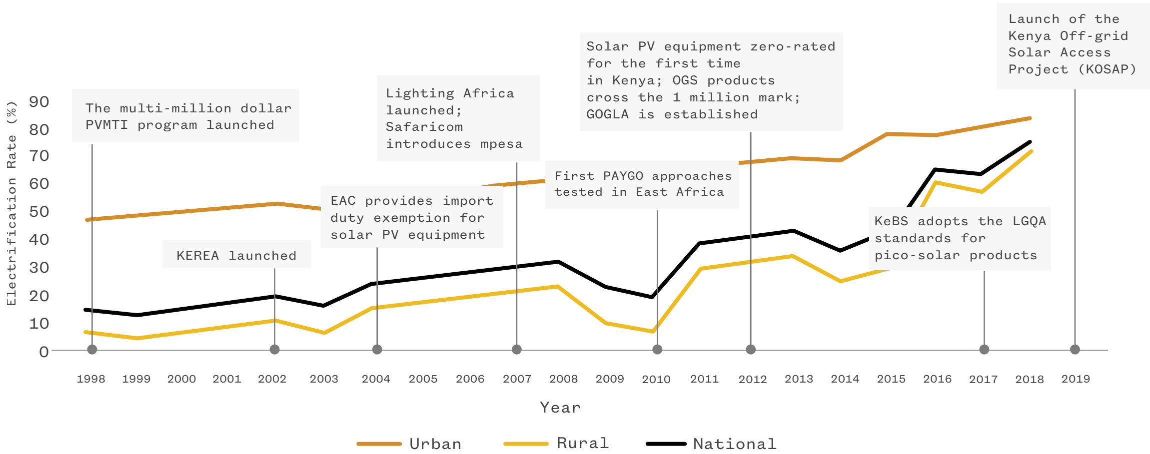


Figure 5: Evolution of electrification approaches in Kenya.
Source: EED Advisory 2021

FIRST WAVE [PRE-1997]

- Formation of ministry of energy
- Emergence and expansion of decentralized approaches
- REMP 1997
- Emergence of schools,hospitals and boreholes powered by OGS
- Energy act of 1997 facilitated the unbunding of Kenya power

SECOND WAVE [1998-2014]

- KEREA formed in 2002
- Energy Act of 2006 establishes REA
- Lighting Africa launched in 2007
- REMP 2009
- Rise in decentralized innovations [PAYGO and energy efficiency]
- Expansion of the OGS market at the households level
- GOGLA established in 2012

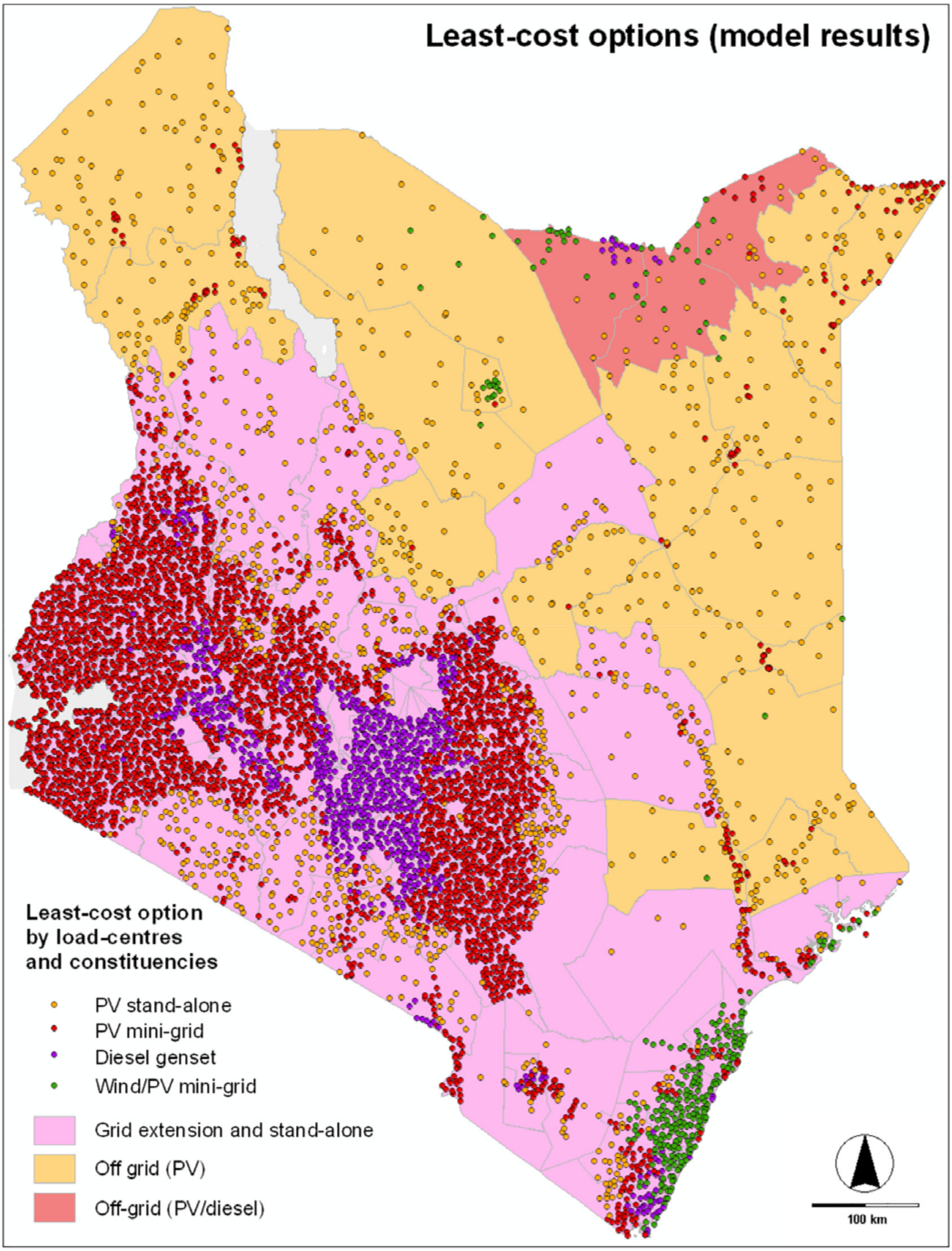
THIRD WAVE [POST-2014]

- Energy Act of 2019 Establishes REREC
- KOSAP launched in 2017
- Several RBF programmes launched to incentivise OGS
- OGS incorporated national electrification planning under KNES
- Draft mini-grids regulation tabled for consultation

The off-grid solar market continues to evolve in response to consumer preferences and innovations in technology and business models. Kenyan households now purchase off-grid solar appliances and productive use equipment in addition to lighting solutions. It is important to better understand the cost benefit of decentralized energy solutions in areas that are not connected to the grid. Research conducted by Moner-Girona et al (2019) and summarised in Figure 6 provides such an analysis.[46]

Figure 6: Least-cost electrification options by load centres and constituencies.

Source: Moner-Girona et al, 2019



3.3 Off-grid solar appliances: an emerging sector

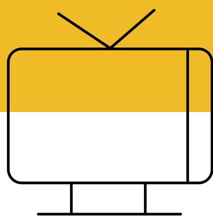
Due to expanding distribution channels, innovative business models and the steady decline in the cost of solar technology, the uptake of off-grid solar appliances[47] and equipment is gaining traction around the world. Solar powered televisions, radios, refrigerators, water pumps and fans show particular promise. Globally, between 1.4 and 5 million off-grid solar televisions, fans and refrigerators were sold in 2019.[48] One affiliate, GOGLA, reported sales of 221,000 televisions, 225,000 radios, 238,000 fans, 3,400 solar pumps and 4,400 refrigerators in the period January 1 to June 30 2020.

In Kenya, 69,361 off-grid solar appliances were sold in the second half of 2018, 67,343 of which were televisions.[49] Following televisions, water pumps are the second most popular off-grid solar appliance in Kenya. The demand for fans in Kenya is relatively low.

Investors and development partners are increasingly adopting solar powered productive use equipment like water pumps to achieve development goals in the agricultural sector. These goals include increasing agricultural productivity, growing micro industries and improving livelihoods in rural areas.

There is great potential for market growth in the off-grid solar appliance and equipment sector as the financing, prototyping and energy-efficient manufacturing environment continues to improve and as innovative programs such as the Kenya Off-Grid Solar Access Project are rolled out.[50] VeraSol is in the process of developing a quality assurance framework for off-grid solar appliances.

69,361 OFF-GRID SOLAR APPLIANCES WERE SOLD IN THE SECOND HALF OF 2018, 67,343 OF WHICH WERE TELEVISIONS.



04 Developing a consumer-based survey of off-grid solar in Kenya

This study developed a national survey to assess consumer interactions with quality verified and non-quality verified off-grid solar lighting and home system products and to better understand the off-grid solar appliance and equipment market at the household level. All 47 counties in Kenya were surveyed and the total sample size was 3,915 households. The structure and methodology of the survey is described in the following sections. Seven counties, Machakos, Kitui, Narok, Homa Bay, Siaya, Migori, and Kilifi were over-sampled because they had the largest solar penetration according to 2019 Kenya National Bureau of Statistics census data. These seven counties are collectively referred to as off-grid counties in this report.

4.1 Data collection and sampling methodology

This study conducted a survey in January and February of 2021 using Computer Aided Personal Interview (CAPI) software. The survey team comprised of consultants from EED Advisory and over 217 enumerators spread across Kenya's 47 counties. Enumerators were trained at a central location in each county and deployed after demonstrating proficiency with data collection platforms SurveyCTO and SW Maps. The survey used geospatial data to pre-select respondents (households), and a two-stage cluster sampling strategy was adopted as the most efficient approach for large-scale surveys. This selection and sampling process is described in the following sections.

Stage 1 of the cluster sampling strategy

The first stage of the sampling strategy was to randomly select primary sampling units (PSUs), also called enumeration areas or clusters, across the 47 counties. The primary sampling units were generated based on a spatial algorithm developed by EED Advisory, the National Autonomous University of Mexico and Stockholm Environment Institute. The algorithm defines discrete population enumeration areas bounded by Kenya's 7,149 sub-locations. Each enumeration area contains roughly 200 households or 1,000 people. Enumeration areas were selected using a two-tier stratification plan by county and rural or urban residence as follows:

- **County:** Household selection for the core and off-grid markets was proportional to each county's population based on the 2019 Kenya National Bureau of Statistics census.
- **Rural-Urban:** Counties were divided into rural and urban areas based on the definition of rural and urban from the 2019 Kenya National Bureau of Statistics census. This resulted in a 70:30 rural to urban split at the national level.

The sampling technique used was random sampling without replacement (SRSWOR).

Stage 2 of the cluster sampling strategy

In the second stage of the sampling strategy households were randomly selected to create secondary sampling units (SSUs) from the primary sampling units determined in the first stage. The distribution of the primary sampling units was done in a manner that maximizes differences between households within a primary sampling unit and minimizes the differences between primary sampling units such that the intra-cluster correlation is close to zero.

Studies have shown that for constant overall sample size, increasing the number of primary sampling units increases statistical power faster than increasing the number of secondary sampling units. This is because the former results in uniform distribution and saturation of secondary sampling units over the sampling space.[51,52] The sampling technique for this second stage remained random sampling without replacement (SRSWOR).

Respondent identification

To identify respondents the survey used a publicly available high-resolution (30 meters or 1 arc-second) population distribution mapping of Kenya developed by the Center for International Earth Science Information Network in collaboration with Connectivity Lab and Digital Globe.[53] This distribution map is a raster dataset of Kenya's settlements derived from land use classification. The map is based on Landsat satellite imagery where each pixel represents a building or structure on the earth's surface. Converted to point data, a settlements dataset can be developed to provide an exhaustive listing of households. Random selection of target households was generated from this dataset. Additional households (10% of the target sample) were also selected as replacements for households that would be unwilling or unavailable to participate in the survey.

Selected households were loaded onto SW Maps, an android-based geospatial application that allows interaction between geospatial layers and real-time navigation using Global Positioning System (GPS) and global navigation satellite system (GLONASS). Each household was labelled with a unique number for ease of identification by the survey team.

4.2 Survey methodology

The survey collected data in strict adherence to the Kenya Ministry of Health COVID-19 protection measures. This included providing every enumerator and respondent with a mask, carrying out data collection in an open space, and maintaining a minimum distance of one meter in interactions. The EED Advisory team was on the ground to review the data as it was submitted by enumerators. Several key informant interviews were also conducted with industry stakeholders and solar manufacturers and solar PV manufacturers and distributors.

> ON AVERAGE EACH SURVEY TOOK 30 - 45 MINUTES FOR HOUSEHOLDS WITH SOLAR PRODUCTS AND APPLIANCES AND 5 - 10 MINUTES FOR HOUSEHOLDS WITH NO SOLAR PRODUCT OR APPLIANCE.

The survey investigated respondent experiences with off-grid solar lanterns, lighting systems, home systems, appliances and productive use equipment at the household level. Information was based on off-grid solar products and appliances that were currently in use. Questions ranged from pricing, durability, after-sales service, warranty, availability, accessibility, quality and service level. To distinguish between quality-verified and non-quality verified products, enumerators photographed the brand and model of items where respondents allowed this. A list of products that had been quality verified based on the Lighting Global Quality Assurance framework was made available by VeraSol and was used to classify products surveyed as quality-verified or non-quality verified.

To add value to the survey and provide contextual information, respondents were also asked questions on connection to the grid, the gender of headship in the household, monthly income levels, economic activities and the type of household dwelling. The purpose of this was to build knowledge on current rates of electrification, better understand the relation between grid connectivity and off-grid solar adoption and to consider the social and economic attributes of households surveyed.

4.3 Accounting for areas with high prevalence of solar products

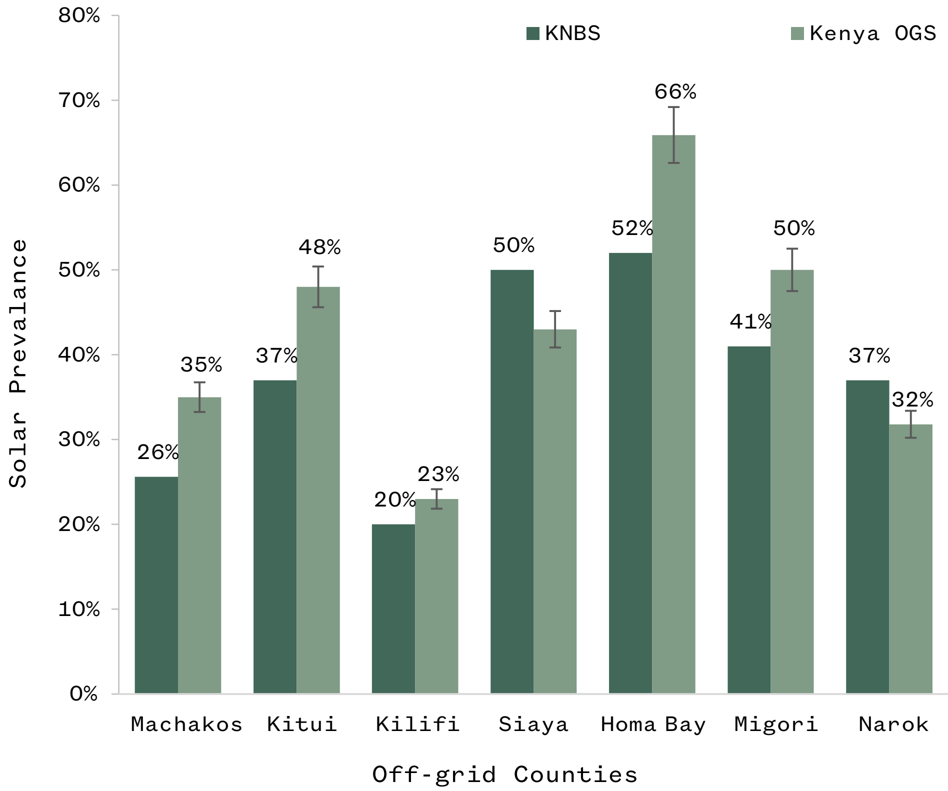
The 2019 Kenya Population and Housing Census identified seven counties—Machakos, Kitui, Kilifi, Siaya, Homa Bay, Migori and Narok—as having the highest prevalence of off-grid solar products in the country. This survey oversampled in these counties and conducted a validation exercise as described below. The purpose of oversampling in the seven counties was to boost the total number of households in the core sample size and achieve a statistically representative sample across the off-grid counties and the entire data set as a whole. Oversampling was carried out in urban areas.

Figure 7 checks surveyed data for the seven counties with a high prevalence of solar against the Kenya National Bureau of Statistics 2019 census.

These seven counties have been dubbed off-grid counties, and it was found that the differences in solar prevalence rates across the two data sets were within the 5% margin of error, apart from Kitui, Siaya and Homa Bay where this difference was within a 7% margin.

These percentage differences can be attributed to the two-year gap between the census and this survey, and the robustness of this survey's sampling and respondent selection process is otherwise confirmed.

Figure 7: Comparison of survey results against 2019 Kenya Population and Housing Census



4.4 Survey limitations

The survey developed for this study sought to capture information on quality verification status by asking two main questions:

i. What is the brand name of the product?

ii. What is the brand model of the product?

Enumerators had an option to photograph the product and its serial number where respondents were comfortable and allowed for this. Training of enumerators prior to beginning the survey provided examples of product brands and models likely to be encountered on the ground, and described features to consider while classifying products.

During the data cleaning process, the EED Advisory team verified the brand name and brand model captured by enumerators. The team found that while brand names were adequately captured in most cases, there were significant challenges in capturing the brand model. This is therefore noted as a limitation, particularly as brand model plays a key role in differentiating quality verified and non-quality verified products. For this reason, only products with images captured (46%) could be definitively verified for the brand and brand model. These products were used in analyses comparing quality verified and non-quality verified products.

05 Survey results: Analysis of off-grid solar products in Kenya

The survey developed for this study was used to analyse how quality verified and non-quality verified off-grid solar products were experienced by respondents from the perspective of durability, quality, after-sales service, performance, accessibility and affordability. Overall, 80% of all respondents reported being satisfied or very satisfied with their off-grid solar product. Moreover, 76.5% were satisfied with the durability, 73.6% were satisfied or very satisfied with the pricing, and 72.2% were satisfied with after-sales services received. The following sections explore these and more results from the survey.

5.1 Brand and quality verification status

During the study, 4,195 interviews were conducted. Of these, 1,414 respondents reported owning a solar product. The first step in analysis was to identify brand names and models. Brand identification was carried out as data were collected during the survey and later as the data were cleaned. A total of 1,205 products were identified by brand name. The methodology and extent of information captured included:

- Brand identified through enumerator observations and photograph of product: 761 products.
- Brand identified but no purchase date indicated: 45 products.
- Brand identified, product categorized as a solar lighting system, solar home system or solar lantern and year of purchase indicated: 30 products.

For 579 products where the brand name or model was not available initially, 453 follow-up phone calls were made. Through these calls and using descriptions of the brand and brand model, an additional 167 products were categorized.

To assess quality verification status, 650 products were definitively categorized in the data analysis. In these cases, a photograph of the product was taken, and these images provided a basis for validating the product model (as well as brand), which is key information for determining the quality verification status.

Among all products where a photograph was available,

- 471 were categorized as quality verified,
- 117 as non-quality verified, and
- 22 products could not be classified and were categorized as unknown.

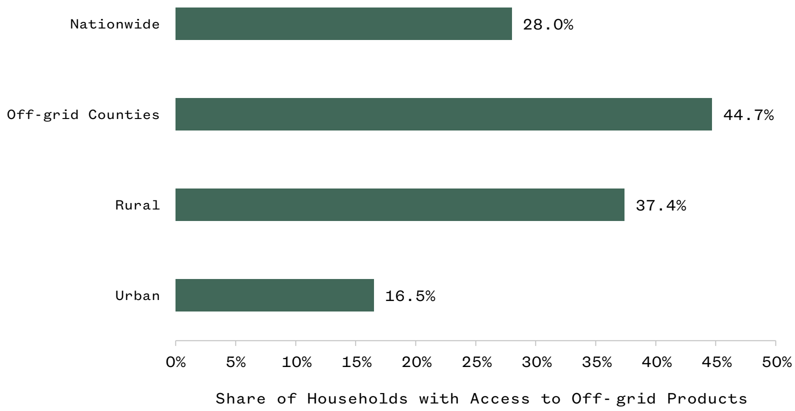
Where analysis in this study did not require comparison with respect to the quality verification status, the full data set of 1,414 entries was used.

5.2 Access to off-grid solar products

Survey data showed that 28% of households interviewed had access to at least one stand-alone off-grid solar product (Figure 8). These households used a solar lantern, a solar lighting system or a solar home system. Extrapolating this data nationally, 28% represents 3,372,044 Kenyan households. Similarly, 2,529,033 households or 21.5% are estimated to use off-grid solar for their main source of lighting.

These findings are consistent with the 2019 Kenya Population and Housing Census, which reported a stand-alone off-grid solar product access rate of 24.5%, and also with the World Bank's multi-tier framework country report, which indicated an adoption rate of 22.9%.[54],[55]

Figure 8: Households with access to off-grid solar products per strata



KENYAN HOUSEHOLDS HAD ACCESS TO AT LEAST ONE STAND-ALONE OFF-GRID SOLAR PRODUCT.

Figure 8 also shows that 37.4% of households in rural areas (the equivalent of 2,759,852 households) have access to an off-grid solar solution compared to 16.5% of households in urban areas (769,516 households). Connection to the grid is a likely explanation for this difference. At a national level, survey analysis estimates that 28% of Kenyan households have access to off-grid solar products.

There is a higher rate of access to off-grid solar products for the seven counties identified as having a high prevalence of solar products, or off-grid counties. In these counties, 44.7% of households were found to have access to off-grid solar. These counties are similar in being the more densely populated counties to the west of the country, having lower grid connection rates and having an unreliable grid.[56] The survey found that only 41.3% of households in these off-grid counties have access to grid electricity. Interestingly, the share of households using off-grid solar products as their main source of lighting (39%) is a near match to the households using electricity from the grid (38.1%). A significant number of households with grid connection also reported using off-grid solar as their main source of lighting. For example, in Migori County the survey found that 40.3% of households are connected to the grid while only 34.6% report using grid-connected lighting as their main source of lighting compared to 47.5% using solar energy kits.

5.3 Distribution of off-grid solar products

The survey found that at a national level almost 8 out of every 10 solar products reported were either a solar lantern or a solar lighting system. This result is summarised in Figure 9. Solar home systems and component-based systems accounted for 14.0% and 6.9% of product types, respectively.

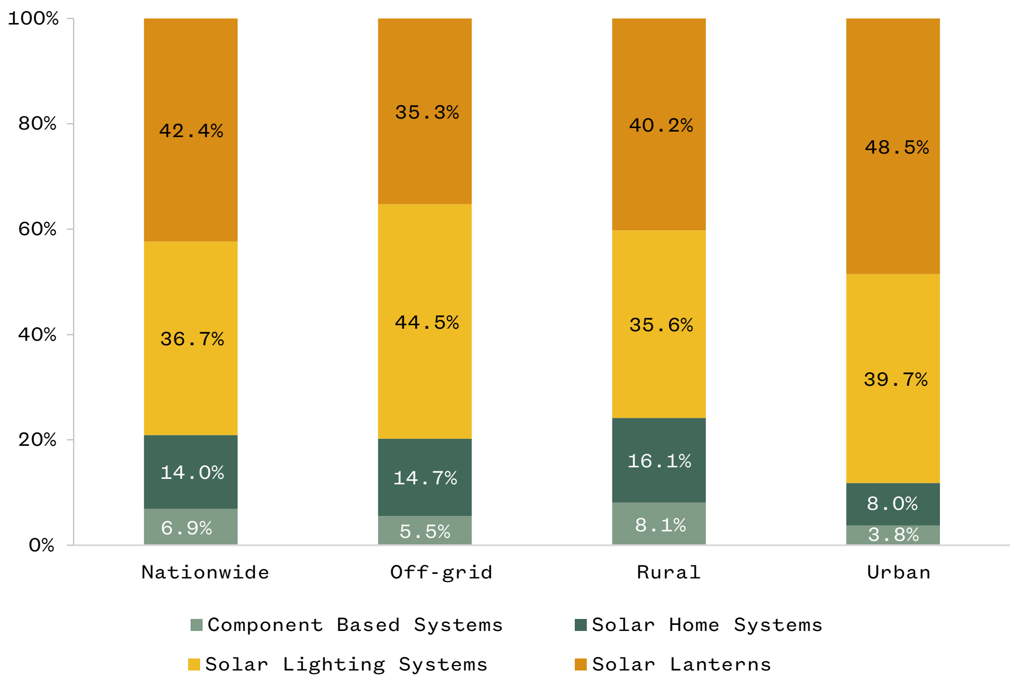
Figure 9 also shows that rural households had 75.8% of the solar products reported as either solar lanterns or solar lighting systems and 16.1% as solar home systems. In urban areas, 83.5% of households were found to use the grid as their main source of lighting compared to 43.5% of rural households. This is the likely reason why most solar products reported for urban households were for lower tier energy solutions such as backup lighting, portable lighting and fixed room lighting. In urban areas, 88.2% of the solar products reported were either a solar lantern (48.5%) or a solar lighting system (39.7%).

From the analysis, 78.1% of the solar lanterns, 81.0% of the solar lighting systems, and 64.7% of the solar home systems were identified as QV. These prevalence rates for quality verified products are higher than pico-PV market estimates reported in previous studies in 2016.[57]

The differences in the prevalence rate are likely due in part due to continued growth which has been led by a vibrant private sector and targeted government programs like KOSAP.[58]

Overall, there are more higher tier off-grid solar products used in rural areas and off-grid counties compared to the urban areas. Component-based off-grid solar systems, which are defined as off-grid solar home systems assembled with components from different brands and usually by the consumer, were found to account for 6.9% of the solar products surveyed. These systems are excluded from quality verification analysis in this study.

Figure 9: Share of off-grid solar products per strata and proportion of products per strata

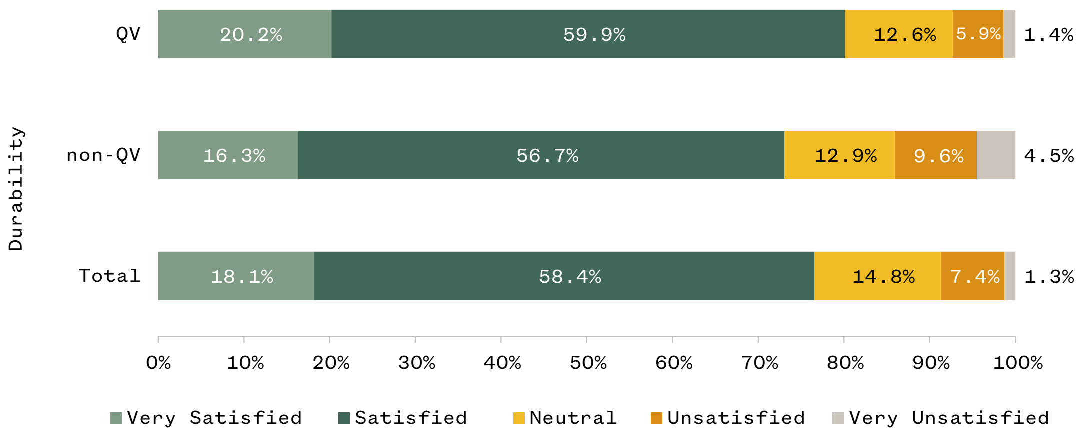


5.4 Product durability

The survey found that respondents had a favourable and comparable level of satisfaction with the durability of their off-grid solar products. Figure 10 shows that 76.5% of respondents reported being satisfied or very satisfied with their solar product, and that there was a similar level of satisfaction between quality verified and non-quality verified products.

Image credit: SunnyMoney

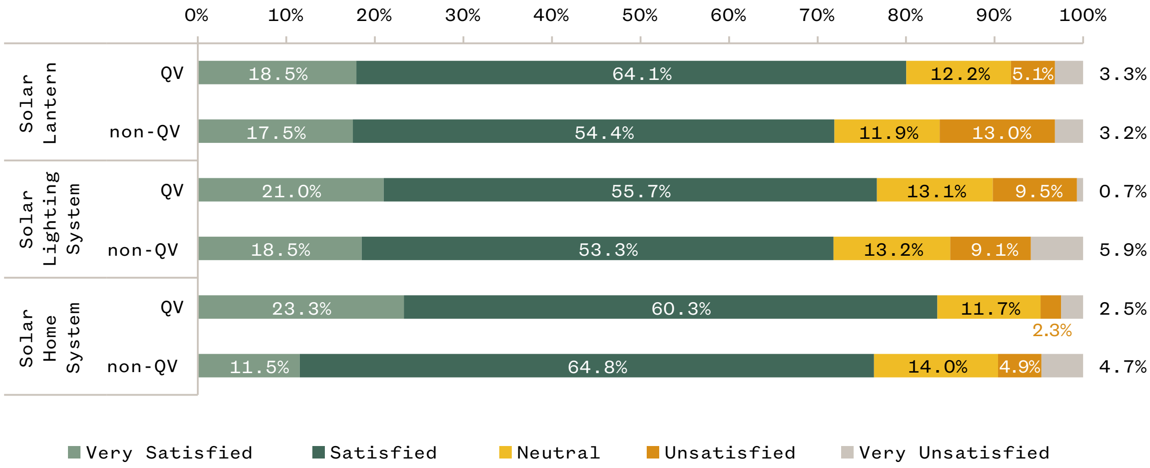
Figure 10: Durability satisfaction levels for quality verified (QV) and non-quality verified (non-QV) off-grid solar products



A comparison along product types found that respondents were most satisfied with the durability of solar home systems, as shown in Figure 11. Both quality verified and non-quality verified solar home systems had the highest reported rate of satisfaction with durability at 83.6% and 76.3%, respectively. In this case there was no statistical significance in the level of satisfaction with durability based on quality verification.[59] Data on solar lanterns showed a similar result with respondents reporting a 72.6% and 71.9% level of satisfaction with durability for quality verified and non-quality verified lanterns, respectively.

Analysis of solar lighting systems showed a statistically significant difference[60] in satisfaction with durability between quality verified and non-quality verified systems. As shown in Figure 11, 76.8% of respondents reported satisfaction with quality verified solar lighting systems compared to 71.8% for non-quality verified systems.

Figure 11: Durability satisfaction level for quality verified (QV) and non-quality verified (non-QV) off-grid solar products by product line



Consumer perception on product life-span

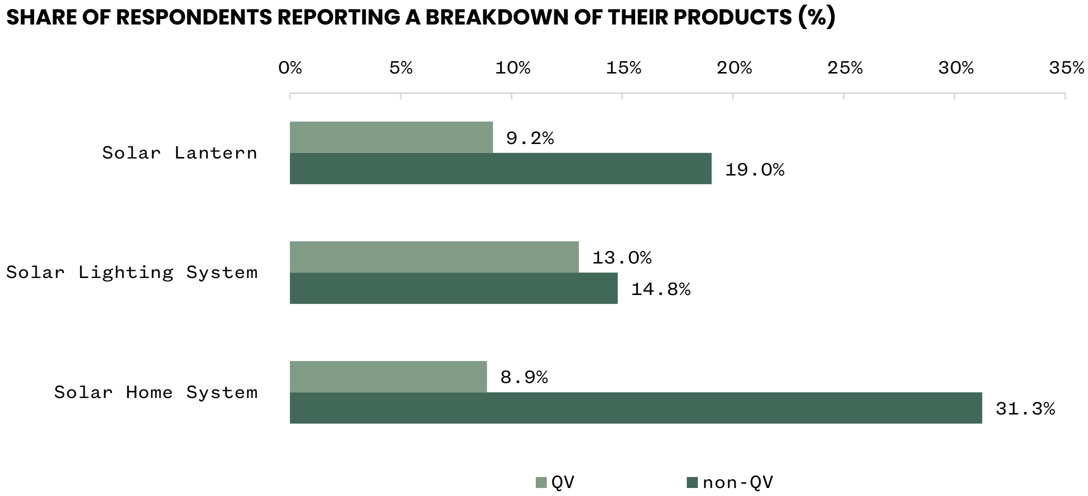
The survey also collected data on expected durability and product life span. Respondents deemed solar home systems the most durable off-grid solar product, with an expected life span of 11 years compared to 9 years for solar lighting systems and 6 years for solar lanterns. The perception of durability based on quality verification varied based on product type. Respondents expected quality verified lanterns to last significantly longer at 7 years compared to non-quality verified lanterns at 5 years.[61] Quality verified solar lighting products were expected to last 10 years, while non-quality verified solar lighting products were expected to last 9 years and in this case there was no statistically significant difference.[62] Similarly, there was no statistically significant difference between the expected life span of quality verified solar home systems (11 years) and non-quality verified solar home systems (9 years).[63]

Incidence of product breakdown

Only 12.8% of respondents experienced a breakdown of their off-grid solar product since purchase. Where products had broken down, the incidences were found to be higher for non-quality verified products across all the product types. Figure 12 shows that 9.2% of quality verified solar lanterns were reported to have broken down compared to 19.0% of non-quality verified solar lanterns. This result was found to be statistically significant.[64] For solar lighting systems, 13.1% of quality verified systems were reported to have experienced break down compared to 14.8% of non-quality verified systems. Solar home systems showed the largest significantly different result, with 8.9% of quality verified home systems breaking down compared to 31.3% of non-quality verified home systems.[65] The low share of breakdown in quality verified solar home systems is likely to explain the reported high level of satisfaction with durability.

Where products had broken down, respondents reported on the period of use the product before breakdown. It was found that there was no significant difference in the time frames before breakdown across product types. Solar lanterns were reported to break down after the first 14 months, solar lighting systems after 10 months, and solar home systems after 8 months. Where there was breakdown all three product types were reported to have broken down only once since the time of purchase. The study found that the cost of repair for owners of quality-verified lanterns was lower at KES 247 compared KES 813 for the owners of non-quality verified lanterns. The cost difference was statistically significant.[66] The cost of repair for quality-verified and non-quality verified solar lighting[67] and solar home systems[68] did not vary significantly.

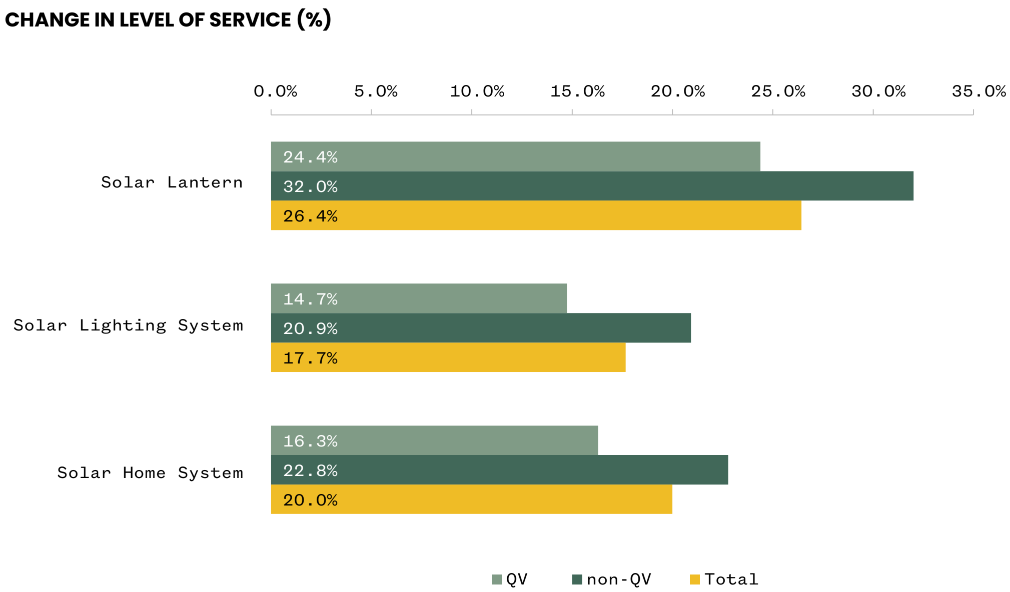
Figure 12: Share of respondents reporting breakdown for quality verified (QV) and non-quality verified (non-QV) off-grid solar products



Level of product service

A change in the level of service for off-grid solar products is defined by changes in the period the product holds a charge, the length of time required to charge, flickering of lights, dimming of lights, or the product suddenly going off. 21% of respondents reported experiencing a change in the level of service of their off-grid solar product. Across the product types, only quality verified and non-quality verified solar lanterns showed a significant difference in change in the level of service as illustrated in Figure 13.[69] The results indicated that 22.8% of respondents with quality verified solar lanterns reported a change in the level of service compared to 44.4% with non-quality verified lanterns.

Figure 13: Proportion of respondents experiencing a change in level of service for quality verified (QV) and non-quality verified (NQV) off-grid solar products



Nature of product breakdown

Durability in off-grid solar products includes:[70]

i. Appropriate protection from water exposure and physical ingress.

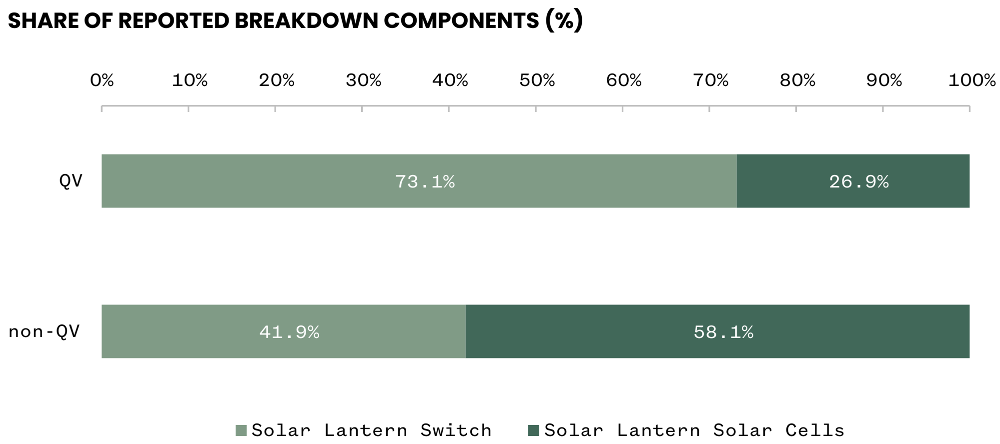
ii. Durable switches, connectors, batteries and light-emitting diode (LED) lights.

iii. The ability for portable connectors to withstand a fall.

Respondents were asked the most common breakdown points of their solar product. The survey did not distinguish assumptions made in the responses, as technical knowledge would be required to accurately identify actual breakdown causes.

Of the 12.8% of total respondents who reported a breakdown of their off-grid solar product, it was found that for non-quality verified solar lanterns the most common problems were associated with solar cells (58.1%) while for quality verified lanterns the most common problems were associated with switches (73.1%).[71] Figure 14 illustrates this result.

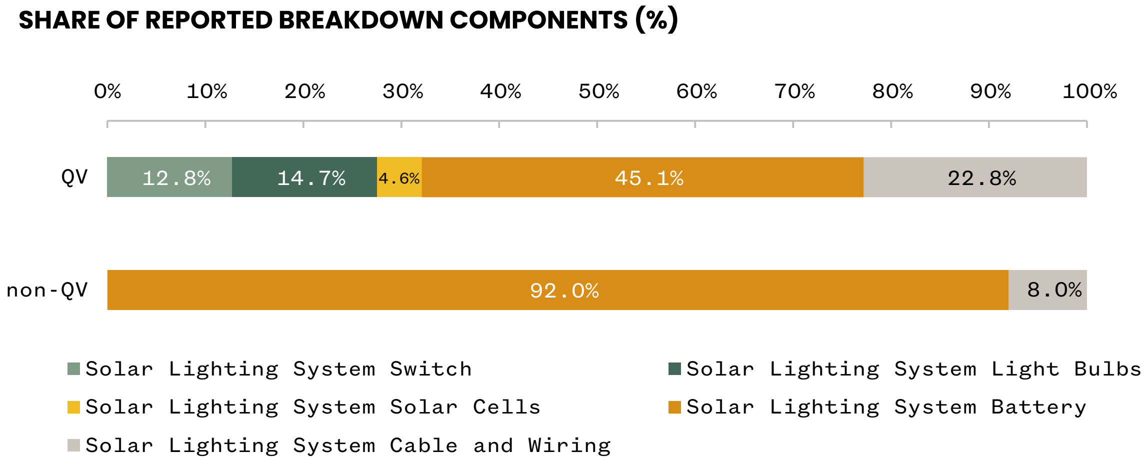
Figure 14: Most common breakdown components of quality verified (QV) and non-quality verified (non-QV) off-grid solar lanterns



For solar lighting systems, Figure 15 shows that issues associated with the battery were cited as the most common reason for breakdowns, with a proportion of **45.1% for quality-verified systems** and **92% for non-quality verified systems**. The next most common cause of breakdown was associated with **cables and wiring** (22.5%) for quality-verified systems and 8% for non-quality verified systems. Respondents also reported breakdowns associated with **switches** (12.8%), **light bulbs** (14.7%), and **solar cells** (4.6%) in quality verified solar lighting systems.

THE BATTERY WAS CITED AS THE MOST COMMON REASON FOR BREAKDOWNS, WITH A PROPORTION OF 45.1% FOR QUALITY-VERIFIED SYSTEMS AND 92% FOR NON-QUALITY VERIFIED SYSTEMS

Figure 15: Most common breakdown components of quality verified (QV) and non-quality verified (non-QV) off-grid solar lighting systems

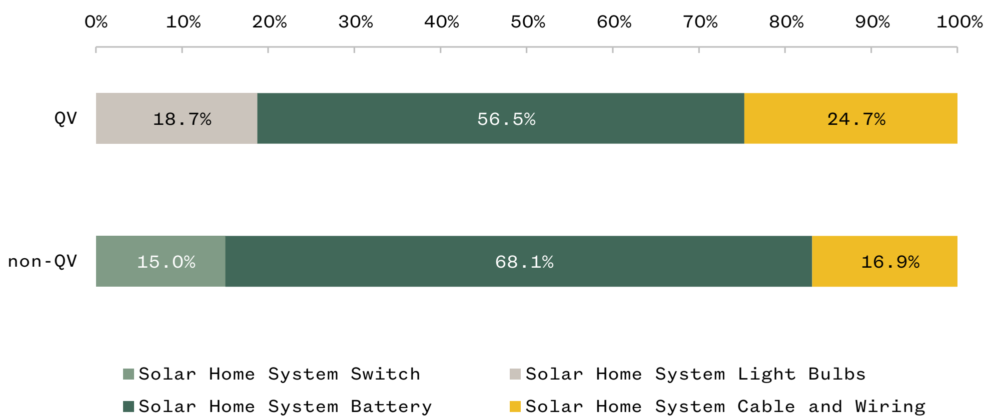


Analysis of data for solar home systems found that, of the 18% respondents who reported a break-down of their solar home systems, the most common associated reason was a problem with the battery (Figure 16). For non-quality verified systems this proportion was 68.1%, while for non-quality verified systems the proportion was 56.5%.[72],[73] It should be noted that the modes of failures for quality verified and non-quality verified assessed were broad, with more failures being experienced by non-quality verified solar home system users. A key informant interview with a representative of the University of Nairobi Lighting Lab revealed that non-quality verified products often failed tests on battery durability, battery deep discharge protection and battery over-charge protection.

Figure 16 also shows that breakdowns associated with light bulbs (18.7%) and cable and wiring (24.7%) occurred in quality verified solar home systems at a higher rate than non-quality verified products (0% for light bulbs and 16.9% for cables and wiring). A study testing 18 non-quality verified off-grid solar products in Kenya against the Lighting Global Assessment framework found that all the products tested passed lumen maintenance and cable testing.[74]

This implies that many non-quality verified products have a similar performance on lumen maintenance and wiring compared to quality verified products. It should be noted that none of the respondents reported a breakdown associated with solar cells. (Figure 16).

Figure 16: Most common breakdown components of quality verified (QV) and non-quality verified (non-QV) solar home systems



Comparison to laboratory testing

Previous evaluation of the durability of the best-selling non-quality verified off-grid solar pico-PV products found that 100% of the products met physical ingress protection requirements and 79% met the requirements for physical durability.[75] As is evident from the findings of this study from the consumer's perspective, the differences observed during laboratory testing are less pronounced during use in the field.

5.5 Warranty

Under the Lighting Global Quality Assurance framework, off-grid solar products are required to include a consumer-facing warranty, but the quality verification process does not include an assessment of whether this requirement is honoured at the point of sale.[76]

Among survey respondents, 66.7% reported having received a warranty with the purchase of their off-grid solar product, with owners of solar home systems reporting the highest rate (81.2%), followed by solar lighting systems (75.3%) and solar lanterns 50%).

Analysis on the basis of quality verification expected to find 100% of quality verified products were sold with a warranty. The survey instead found that only 68.8% of households reported purchasing a quality verified products with a warranty compared to 52.4% of households purchasing a non-quality verified product with a warranty.[77]

Figure 17 summarizes this assessment across product types. There was a significant difference in the share of households receiving warranty for quality verified solar lanterns compared to non-quality verified solar lanterns, and there was a similar result for quality verified solar lighting systems compared to non-quality verified systems.[78],[79] Among solar home system users, 88.7% of households with quality verified systems reported having received a warranty compared to 79.6% of households with non-quality verified systems, with no statistically significant difference in this result.[80]

Figure 17: Share of respondents with warranty for quality verified (QV) and non-quality verified (non-QV) off-grid solar products

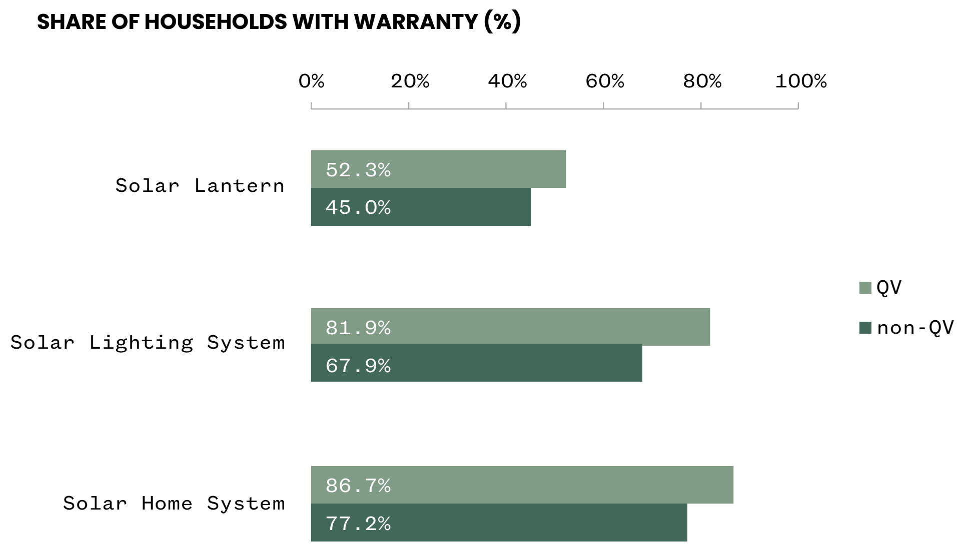


Image credit: SunnyMoney

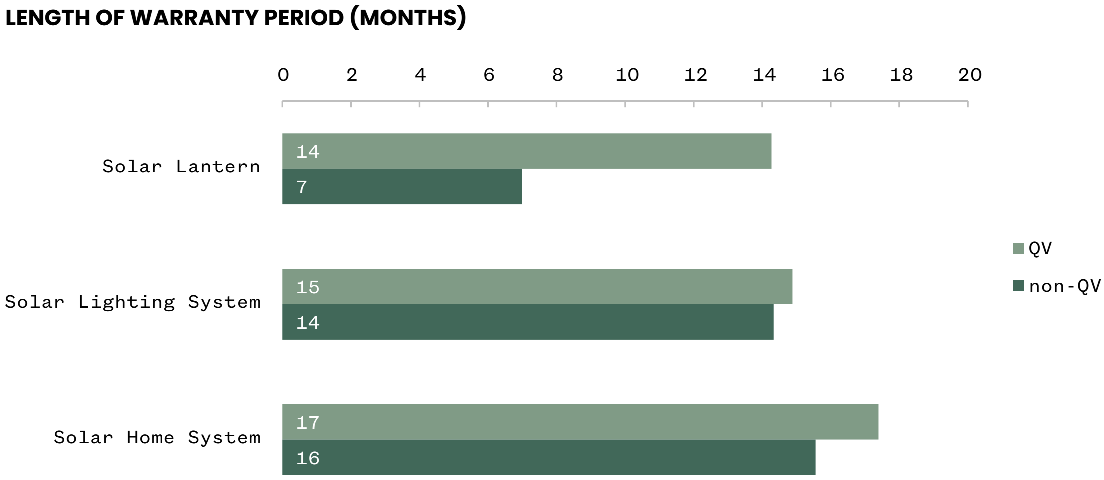
Warranty services

Survey results found that for respondents who did not receive a warranty, 9.1% asked about warranty services with the purchase of their quality verified product but none was available. The larger proportion of respondents who did not receive a warranty (90.9%) did not inquire about the service suggesting they may have not been aware of this service offering. It was also found that less than 1% of respondents' rate warranty as their first or second reason for purchase.

Manufactures and distributors of quality verified and non-quality verified off-grid solar products adopt different retail models for their products. Where micro-franchises are involved, agents can fail to offer or honour a warranty.

Manufacturers and retailers of quality verified off-grid solar products are expected to inform consumers of warranty services before purchase. Where a warranty was offered, the survey found that the warranty period did not vary significantly between quality verified and non-quality verified solar lighting systems[81] and solar home systems[82]. On average, solar home systems had a warranty of 16 months while solar lighting systems had a warranty of 15 months. The warranty for quality verified solar lanterns and non-quality verified lanterns differed significantly with warranty periods of 14 months and 7 months respectively (Figure 18).

Figure 18: Length of warranty offered for quality verified (QV) and non-quality verified (non-QV) products

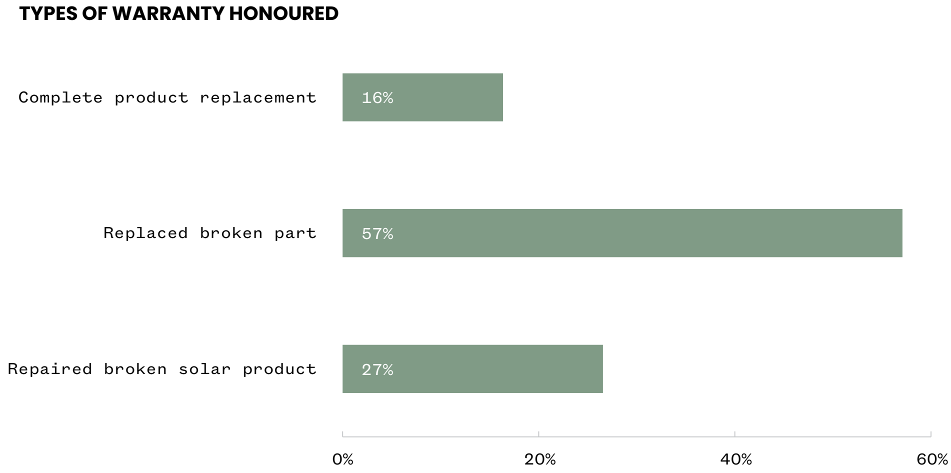


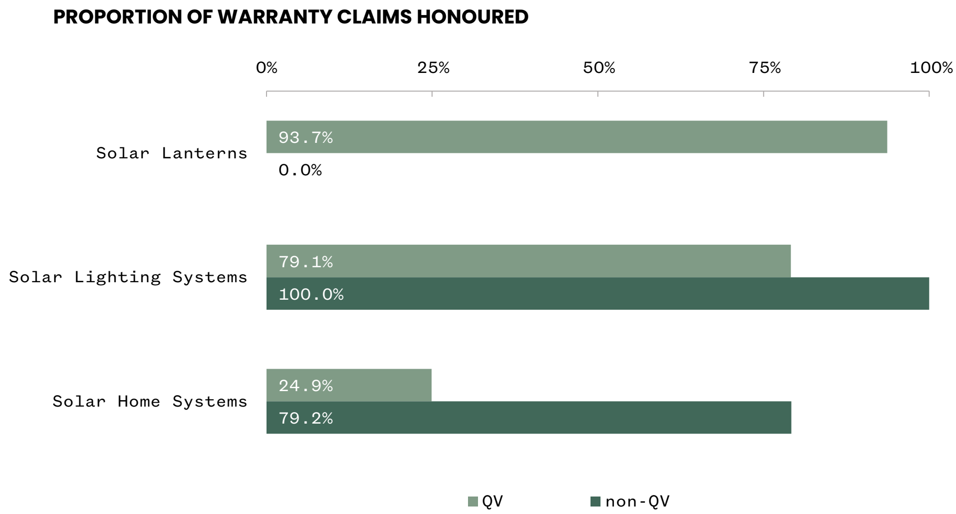
Warranty claims

About 7% of the consumers made a claim related the product's warranty. Figure 19 shows that the services offered with warranty claims on off-grid solar products were mainly replacing a broken part of the product (57%) or repairing a broken product (27%). Respondents reported that 70% of warranty claims across the different off-grid solar product types were honoured. Where a claim was not honoured, the main reason reported was that the claim did not meet the terms of the relevant warranty (87%).

Assessment across product lines found that a higher proportion of claims made on non-quality verified solar home systems and solar lighting systems were honoured compared to quality verified solar home systems and solar lighting systems. The reason provided was that most of the claims made for quality verified products did not meet the terms of the warranty or were reported after the period of warranty (Figure 19). No warranty claims were made for non-quality verified solar lanterns, while 93.7% of the claims made for quality verified lanterns were honoured.

Figure 19: Warranty service and warranty claims honoured for solar lanterns, solar lighting systems and solar home systems





INSIGHT: **COSTS OF REPAIRING OFF-GRID SOLAR PRODUCTS**

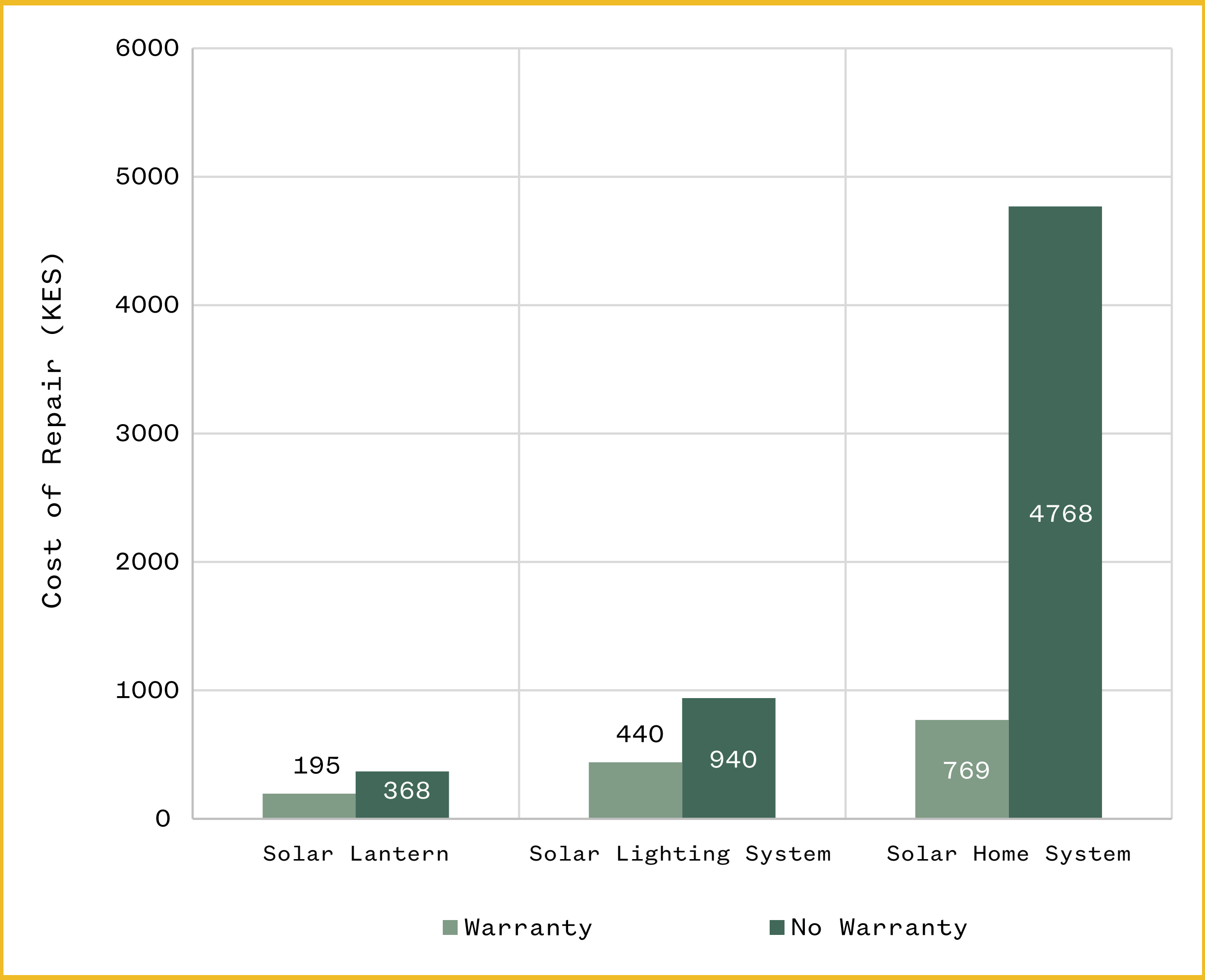
This study found that the total amount used to repair or replace an off-grid solar product for consumers without a warranty is more than double that of consumers with a warranty.

Solar lanterns were found to cost an average of **KES 195** to repair in cases where the product had a warranty, compared to **KES 368** for products without a warranty.

Solar lighting systems with a warranty cost an average of **KES 440** to repair compared to **KES 940** for systems without a warranty.

For owners of solar home systems, the cost to repair the systems without a warranty was **six times more (KES 4,768)** than the cost **(KES 769)** to repair for warranty holders.

The cost of repair across the different product lines is tied to labour and replacing parts. Depending on the terms of individual warranties, distributors and manufacturers may cover labour costs and require the consumer to purchase parts.

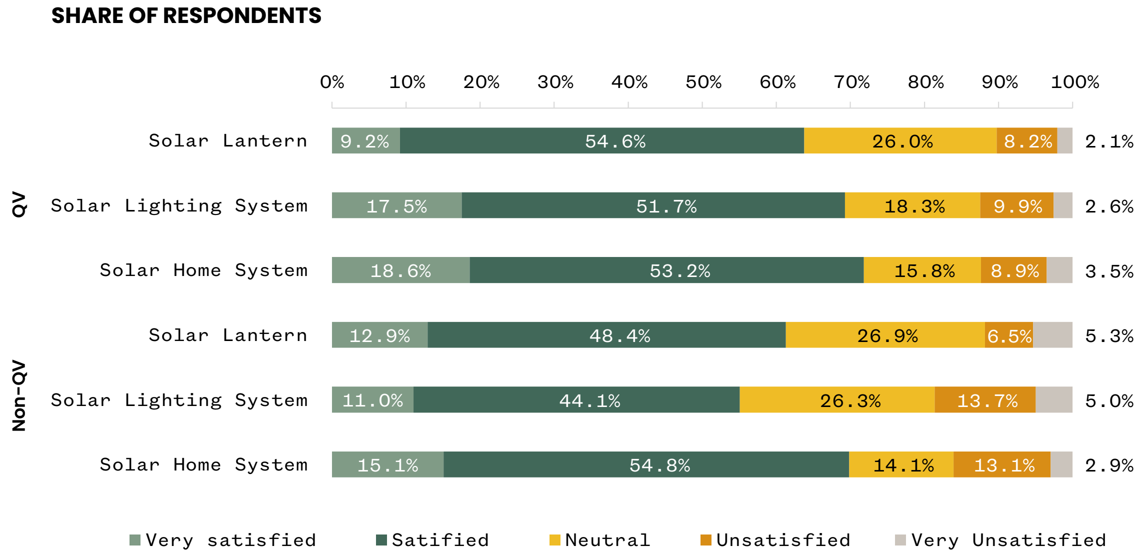



adidas

After-sales service

Respondents reported no significant difference in the level of satisfaction with after-sales services based on whether products were quality verified or non-quality verified across the three off-grid solar product lines surveyed. Overall, owners of solar home systems reported the highest level of satisfaction with after-sales support as shown in Figure 20.

Figure 20: Satisfaction with after-sales support for quality verified (QV) and non-quality verified (non-QV) off-grid solar products

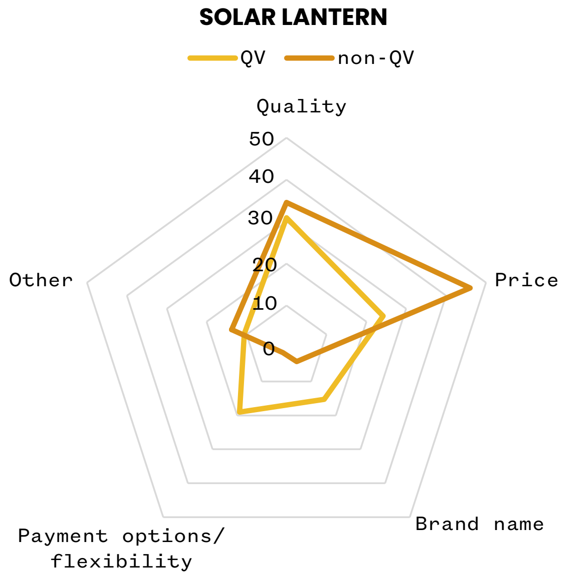


5.6 Factors influencing purchasing decisions

Consideration for purchase

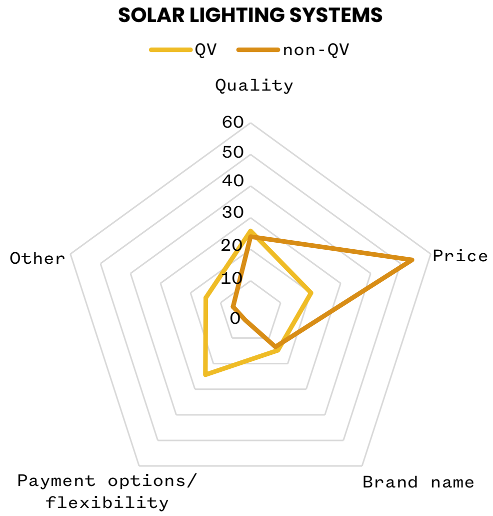
Respondents were asked to state their main and second considerations before purchasing their off-grid solar product. Figure 21 shows that responses varied across product lines and quality verification. For solar lantern users, the main consideration for quality verified lanterns was quality (30.9%) while the main consideration for non-quality verified lanterns was price (46.0%), a significant difference.[83] Of those that purchased quality verified solar lanterns, 19% of respondents considered the payment options available to them compared to only 1.5% of non-quality verified solar lantern purchasers. When asked about their second consideration that influenced their purchase, owners of quality verified solar lanterns cited price (41.6%) while non-quality verified solar lantern owners reported quality (44.1%).

Figure 21: Main purchasing consideration for quality verified (QV) and non-quality verified (non-QV) solar lanterns



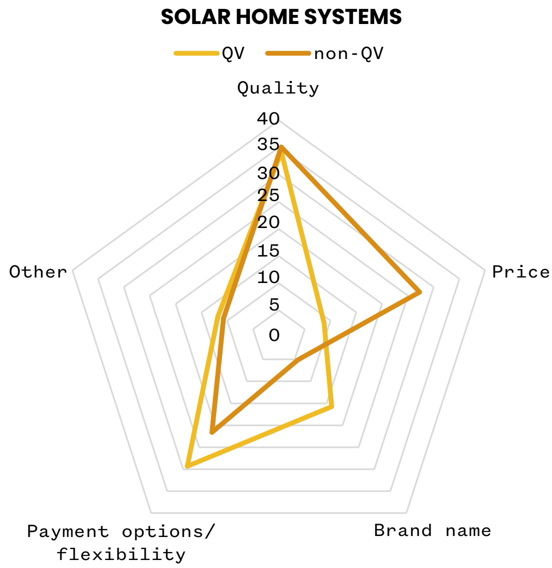
Respondents who owned solar lighting systems[84] also reported considering different factors in their purchasing decision based on whether they owned a quality verified system or a non-quality verified system (Figure 22). The main factor considered when purchasing quality verified solar lighting systems was quality (25%), followed by payment options (24.3%). The main factor considered when purchasing non-quality verified solar lighting systems was price (53.8%), followed by quality (24.0%).

Figure 22: Main purchasing consideration for quality verified (QV) and non-quality verified (non-QV) solar lighting systems



Respondents who owned solar home systems considered similar factors when purchasing the systems regardless of quality-verified status (Figure 23). Among these respondents, 34.5% of quality-verified system owners and 35.6% of non-quality verified system owners considered quality as the main factor when making their purchase. The second factor considered for purchasers of quality-verified systems was payment options (29.4%), while 26.8% of non-quality verified system owners considered price.

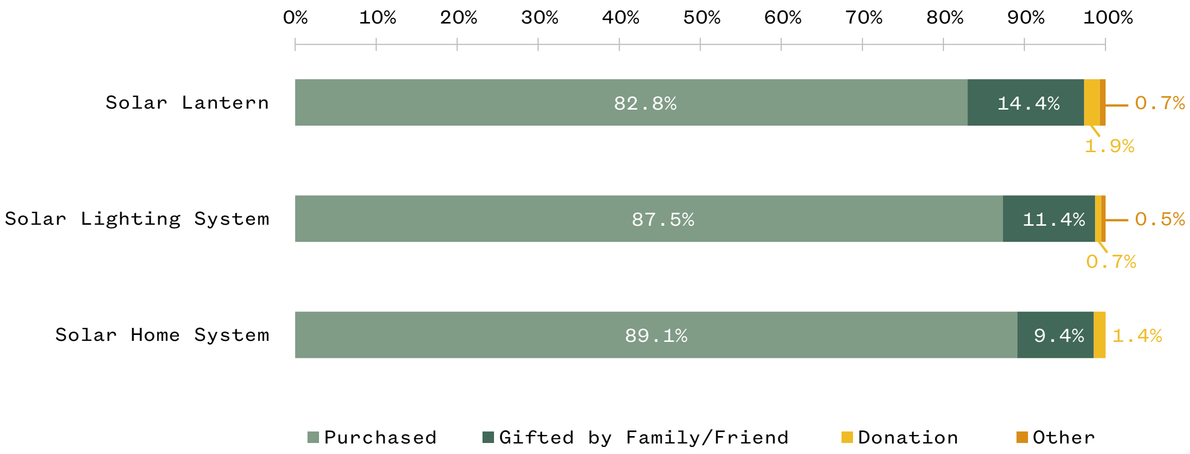
Figure 23: Main purchasing consideration for quality verified (QV) and non-quality verified (non-QV) solar home systems



Means of acquisition

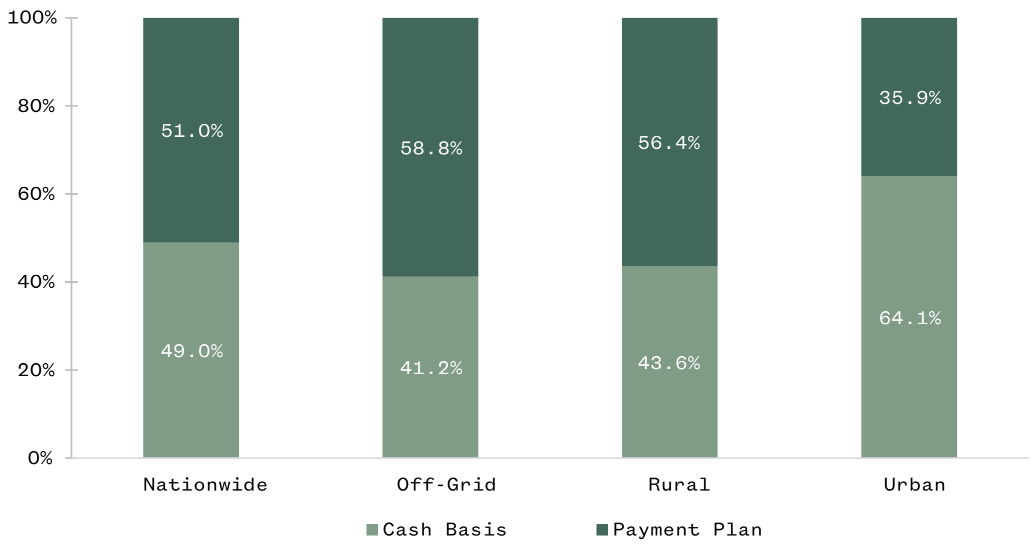
The survey found that 85.8% of households purchased their own off-grid solar product. Extrapolating this nationally equates to 2,933,906 households purchasing their own off-grid solar product. Analysis at the urban, rural and off-grid county levels showed a similar rate of owner purchase ranging from 85% to 87%. Figure 24 shows that where owners did not purchase their own off-grid solar product, gifts from family or friends were the second most common means of acquisition.

Figure 24: Means of acquisition for solar lanterns, solar lighting systems and solar home systems



Survey results also showed that the means of purchase for off-grid solar products was evenly split between a payment plan and cash. At a national level 51.0% of households reported purchasing their product through a payment plan. This result varied based on the location of respondents. Respondents in urban areas mainly reported using cash (64.1%) to purchase their off-grid solar product, while households in rural and off-grid markets made their purchase primarily through payment plans at 56.4% and 58.8%, respectively (Figure 25).

Figure 25: Means of payment for off-grid solar products by strata



Solar lanterns are purchased mostly on a cash basis at the national level (67.2%). The study found a significant association[85] between the means of payment and the locality, that is, but more urban households purchase lanterns on a cash basis (78.3%) compared to both rural (62.6%) and off-grid markets (61.9%). The high urban rate may result from higher income levels and, therefore, a higher purchasing power compared to rural dwellers. Similar trends were observed for solar lighting systems and solar home systems as shown in Figure 26. This figure also shows that solar home systems were primarily purchased using a payment plan whether at a national, urban, rural or off-grid county level.

Figure 26: Means of payment for solar lanterns, solar lighting and solar home systems by strata

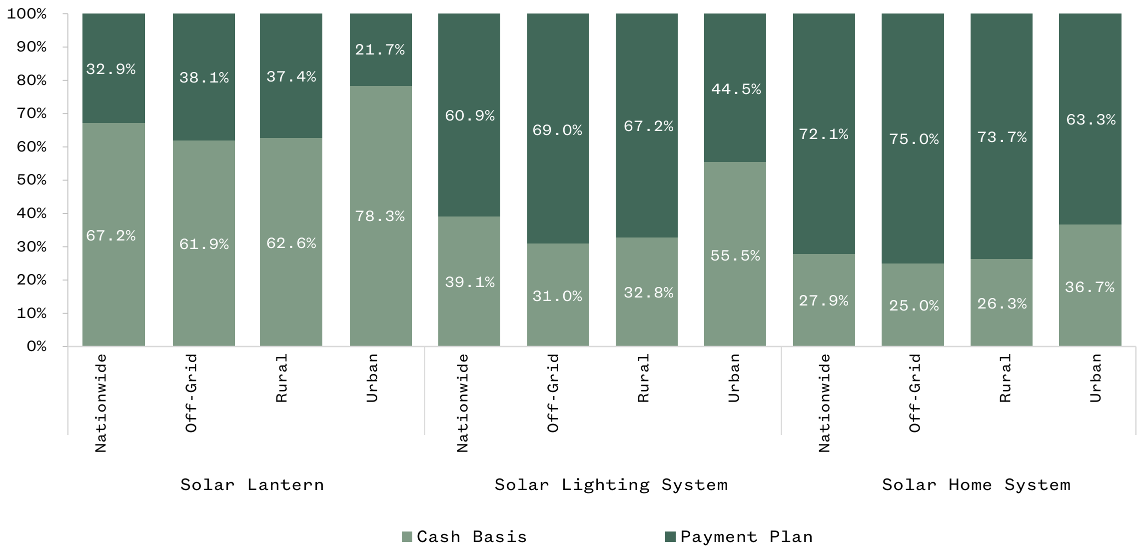
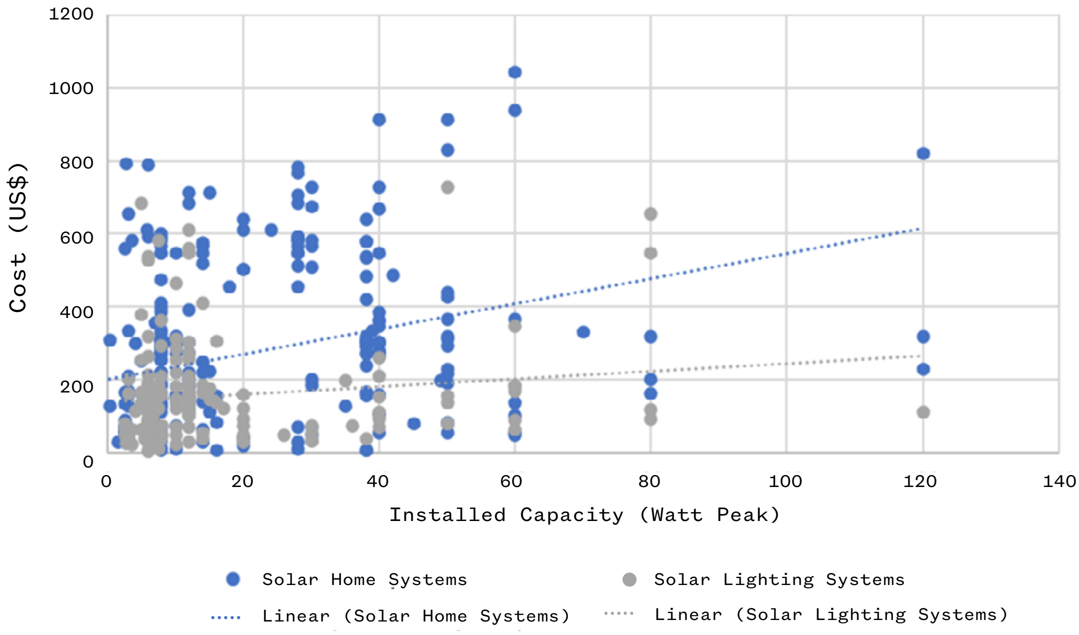


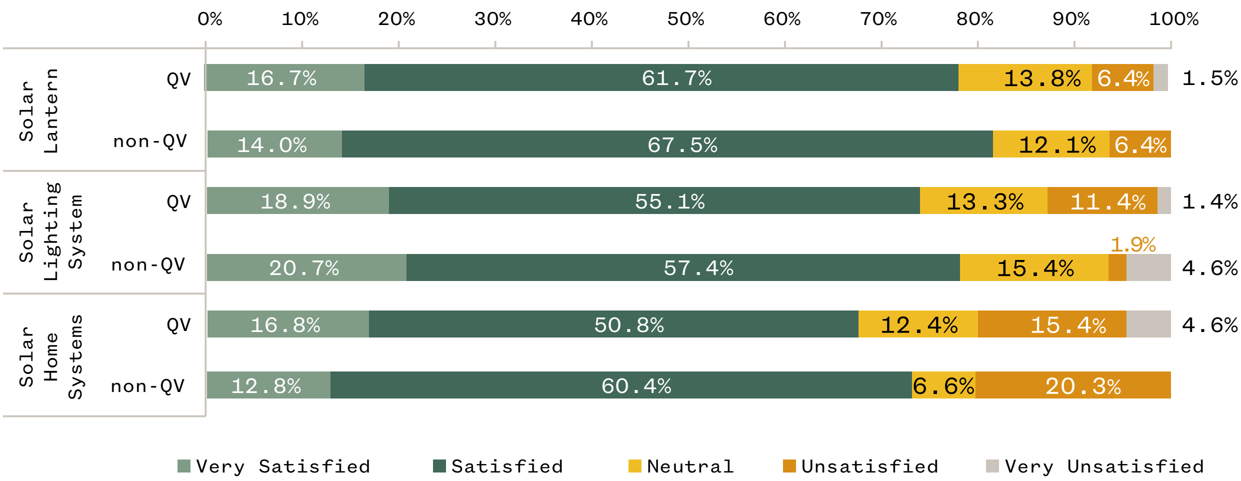
Figure 27: Cost (US$) per installed capacity (Wp) for solar lighting systems and solar home systems



DATA FROM THE SURVEY WAS USED TO ASSESS THE COST PER WATT OF INSTALLED CAPACITY FOR SOLAR LIGHTING SYSTEMS AND SOLAR HOME SYSTEMS (FIGURE 27).

The survey assessed satisfaction with pricing as a gauge of affordability. Overall, respondents of quality-verified off-grid solar products reported similar satisfaction ratings for price. For quality-verified solar lanterns, a rate of satisfaction with price of 76.8% was reported compared to 73.4% for non-quality verified lanterns ($p < 0.916$). Similarly, a rate of 75.1% for quality-verified solar lighting systems was reported compared to 68% for non-quality verified solar lighting systems ($p < 0.790$), and a rate of 74.8% was reported for quality-verified solar home systems compared to 70.9% for non-quality verified solar home systems $p < 0.971$ (Figure 29).

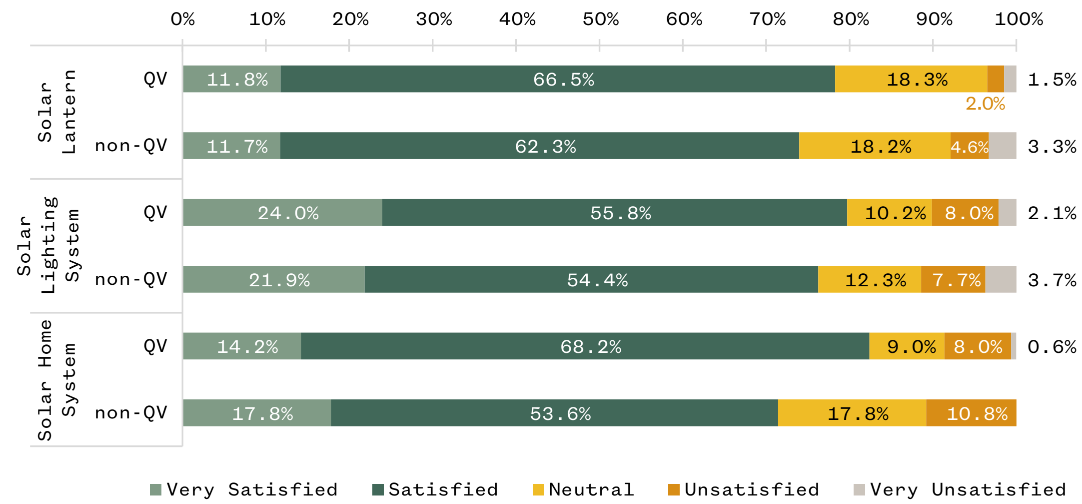
Figure 28: Satisfaction with price for quality verified (QV) and non-quality verified (non-QV) off-grid solar products



Information on performance before purchase

Respondents were also asked to rate their satisfaction with the quality of information presented before purchasing their off-grid solar product. There was no significant difference in satisfaction with information received before purchase ($p > 0.05$) based on quality verification (Figure 30). Of respondents that owned quality-verified solar lanterns, 75.2% indicated either being satisfied or very satisfied with the level of information provided, compared to 69.1% for owners of non-quality verified lanterns. Similarly, 80.5% of respondents with quality verified solar lighting systems indicated satisfaction with information before purchase compared to 69.1% for buyers of non-quality verified solar lighting systems. The values for quality-verified and non-quality verified solar home systems were 85.6% and 76.2%, respectively.

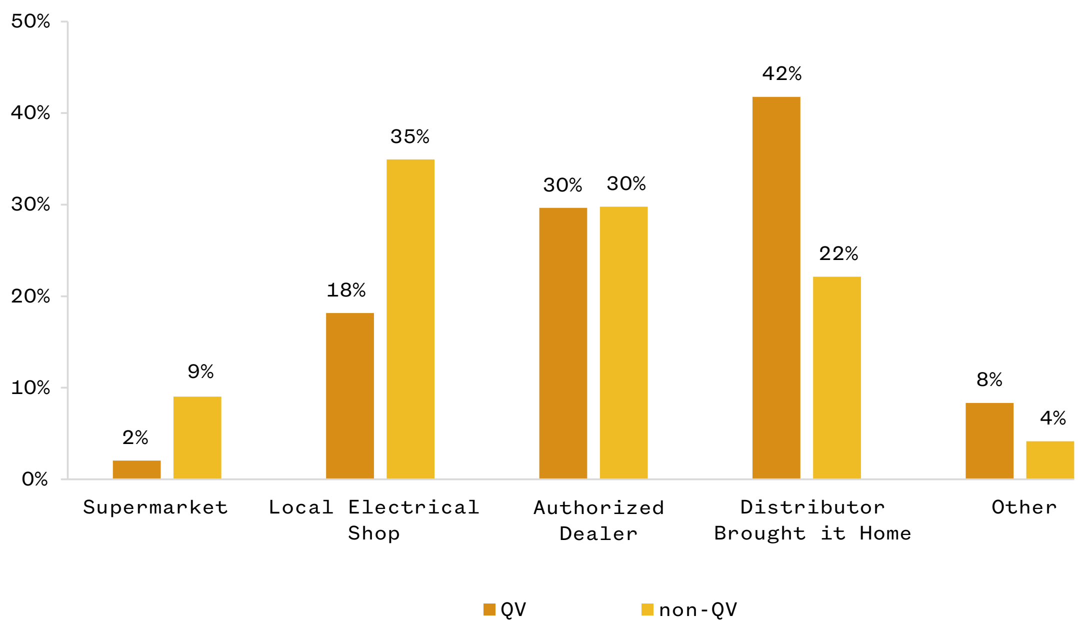
Figure 29: Rating the satisfaction with information on performance before purchase



Access to products

The survey also investigated the point of purchase of off-grid solar products. Figure 31 shows that more respondents with quality verified solar products had their products delivered to their home (42%) compared to respondents with non-quality verified products (22%). This difference is a likely reflection of the distribution approach of affiliated brands and sales strategies to establish long-term consumer relationships.

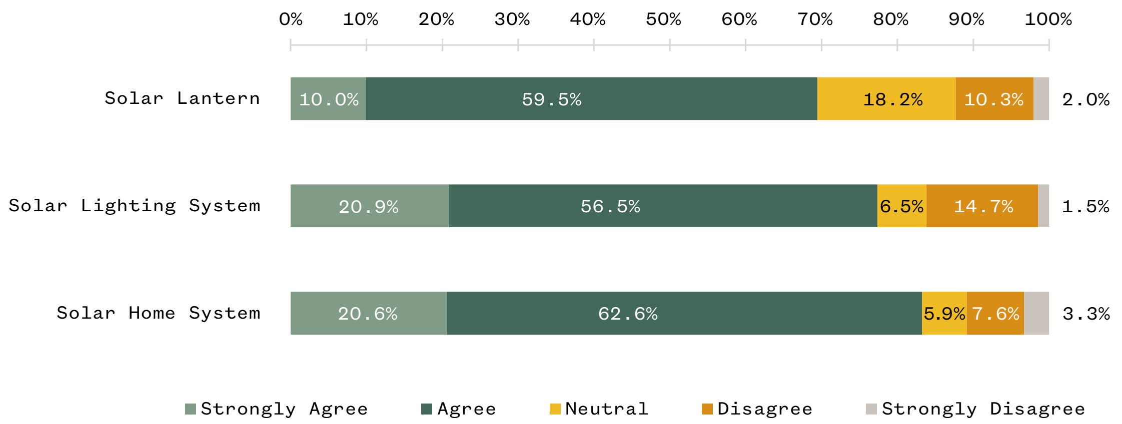
Figure 30: Point of purchase for quality verified (QV) and non-quality verified (non- QV) off-grid solar products



Respondents were also asked about the distance they would need to travel to purchase the same solar product today, and results showed that the average distance is 12.0 km. Respondents that had purchased quality verified products reported shorter distances (an average of 10.9 km) compared to respondents who had purchased non-quality verified products (14.8 km).

Accessibility was also gauged by asking respondents about the ease of finding a distributor, dealer or point of sale for the solar products. Results showed that there was no statistical difference based on quality verification. When compared along product lines, 69.5% of respondents with a solar lantern agreed or strongly agreed the products were accessible compared to 77.4% of respondents with solar lighting systems and 82.6% with solar home systems (Figure 32).

Figure 31: Agreement on the accessibility of off-grid solar products



06 Survey results: Characterization of off-grid solar appliances

The off-grid solar appliance market is nascent and growing quickly. Universal definitions of terms and technology are still evolving, and for that reason this study defines off-grid solar appliances as electrical appliances powered by a stand-alone off-grid solar system either directly (Direct Current or DC appliances) or through an inverter (Alternating Current or AC appliances). Mobile phones and solar lights have not been included in this definition.

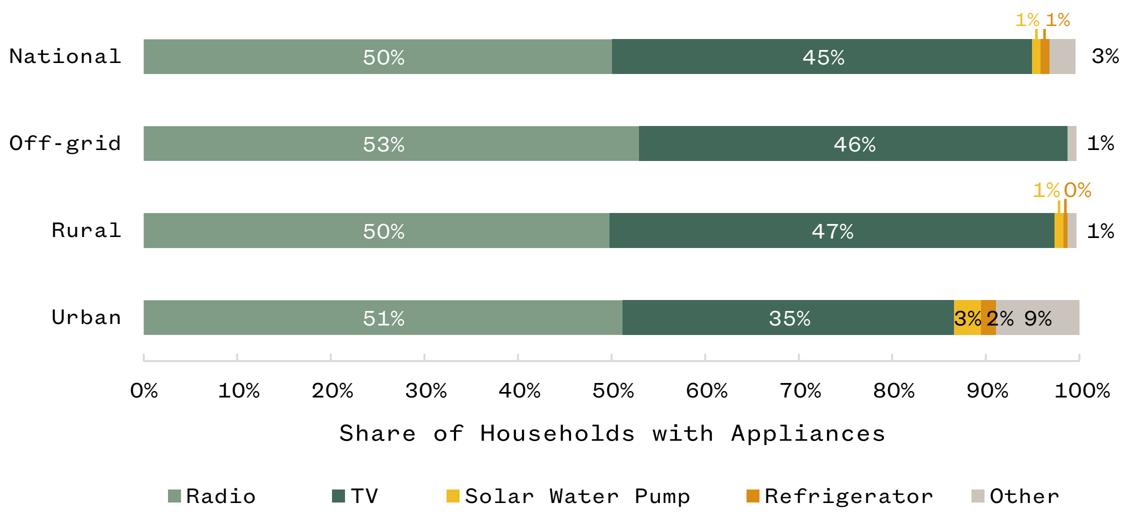
The survey developed for this study collected data on various aspects of off-grid solar appliances to build knowledge on this emerging market. Based on survey results it is estimated that there are 2.4 million off-grid solar appliances at the household level in Kenya. Radios and televisions are overwhelmingly the most popular off-grid solar appliances, accounting for 50% and 45% of the installed base, respectively. The remaining 5% consists of solar water pumps (35,500), solar refrigerators (15,800), and solar fans (69,500).[86, 87]

This dominance of solar televisions and radios can be attributed to the following factors:

- Off-grid solar powered radios and televisions are affordable in the target markets (rural and peri-urban areas).
- These products are routinely sold as part of solar home systems and under payment options such as pay-as-you-go.
- The products are easily accessible and do not require large solar systems to power them compared to other appliances.

Some solar home system companies have incorporated appliances like fans as part of their product offering but this is not as widespread as solar home systems with televisions, radios, and mobile phones.[88] Figure 33 provides a summary of the distribution of off-grid solar appliances surveyed.

Figure 32: Proportional distribution of off-gird solar appliances



6.1 Ownership and projected demand

Current and projected ownership

Survey results found that 74% of all the appliances reported were from rural households compared to 26% in urban households. The likely reason for this is low grid connectivity compared to urban households. Extrapolating these data nationally based on the 2019 Kenya Population and Housing Census data, it is estimated that Kenya had a total of 12.2 million households. The Kenya National Bureau of statistics estimates that the country has an annual growth rate of 2.2%.

This study can therefore estimate that there are 12.7 million Kenyan households in 2021, an increase of 500,000 households from 2019. At the current 12% rate of appliance ownership, this study estimates that 1.5 million households in Kenya own at least one OGS appliance, of which, 1.1 million are in rural areas. Table 2 summarises data collected on solar appliances. The survey was restricted to households and does not include information on solar appliances in commercial entities or social institutions.

Table 2: Total estimated off-grid solar appliances at the household level in Kenya[89]

NO.	APPLIANCE	URBAN	RURAL	NATIONAL
1	Solar Radio 	258,600	942,900	1,201,500
2	Solar TV 	178,900	898,800	1,077,800
3	Solar Pump 	14,700	20,800	35,500
4	Solar Fridge 	8,100	7,600	15,800
5	Other	44,900	24,600	69,500
6	**Total**	**505,300**	**1,894,700**	**2,400,000**

Comparison to market data

The State of the Off-grid Appliance Market Report estimated that 34.5% of Kenyan households owned a television in 2018. This implies that there were approximately 4.2 million televisions in Kenya, powered by the grid or off-grid technology.[90] To estimate the potential for off-grid solar televisions, these figures were split into grid-connected households and off-grid households.

Assuming a grid connection rate of 60%, it can be estimated that 40% of televisions in the country are solar-powered. This approximates the sum of solar televisions in the country to 1.7 million, which is not far from the 1.1 million televisions estimated through this survey. The variation could be a result of the non-inclusion of appliances at institutions and businesses in this survey (Table 2).

Short-term demand

Survey respondents were asked whether they intend to purchase an off-grid solar appliance within the next six months.

Results showed that 12% of all households had an intention to purchase an off-grid solar appliance with the majority (61%) of these being rural households.

Radios and televisions were the most desired solar appliance with 40% and 37%, respectively, of respondents indicating an intent to purchase these appliances. Some households indicated a willingness to purchase more than one appliance. Extrapolating the survey data nationally, a short-term demand of 2.2 million off-grid solar appliances can be estimated from 1.5 million households in the country (Table 3). This analysis is based purely on the desire to own an off-grid solar appliance and not on the willingness or ability to pay. Table 3 also shows that rural households indicated a greater demand for off-grid solar appliances across all appliance types except refrigerators. Urban households represented 55% of the respondents stating their intention to purchase an off-grid solar powered fridge.

Table 3: Short-term (6 months) projected demand for off-grid solar appliances in Kenya[91]

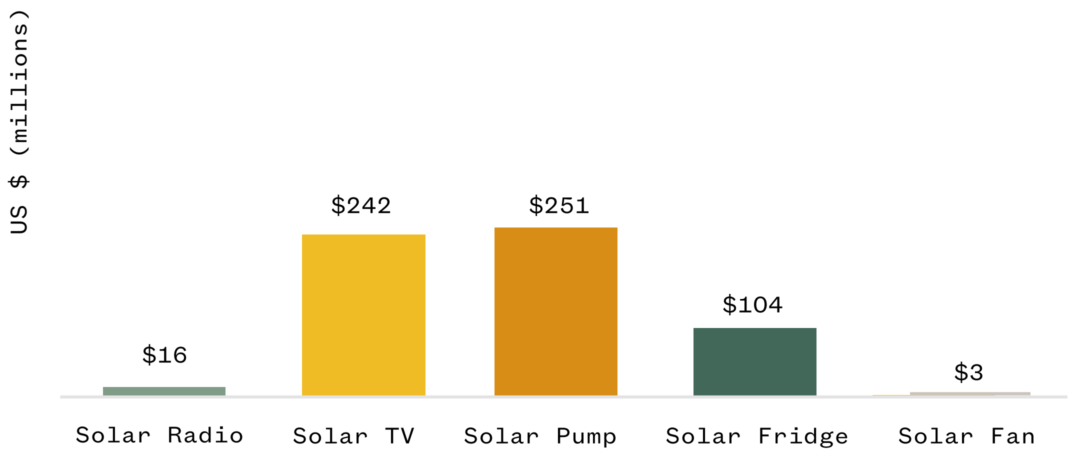
NO.	APPLIANCE	URBAN	RURAL	NATIONAL
1	Solar Radio 	302,100	513,400	815,900
2	Solar TV 	304,400	558,400	863,400
3	Solar Pump 	79,500	130,400	209,200
4	Solar Fridge 	81,200	67,400	148,300
6	Fans 	13,400	50,400	63,800
7	Other	45,600	39,600	86,000
	Total	**826,200**	**1,359,500**	**2,186,600**

This assessment of projected short-term demand can be used to define the sales opportunity for appliances in the off-grid solar sector. The recent 2021 Appliance Data Trends Report provides the following estimate of prices:[92]

- **Television — 200 US$**
- **Refrigerator — 7 US$/L assuming a 100-litre fridge**
- **Fan – 40 US$**
- **Solar pump – 1,200 US$**
- **Radio – 20 US$**

The opportunity for off-grid solar appliances can therefore be estimated at $US 615 million based on the aspirations of respondents to purchase a solar appliance over a six month period after the survey. However, the study notes that the aspirations may not directly translate to a ready market size. Figure 34 provides a breakdown of this estimate based on appliance type.

Figure 33: Addressable market size for off-grid solar appliances in millions of US$



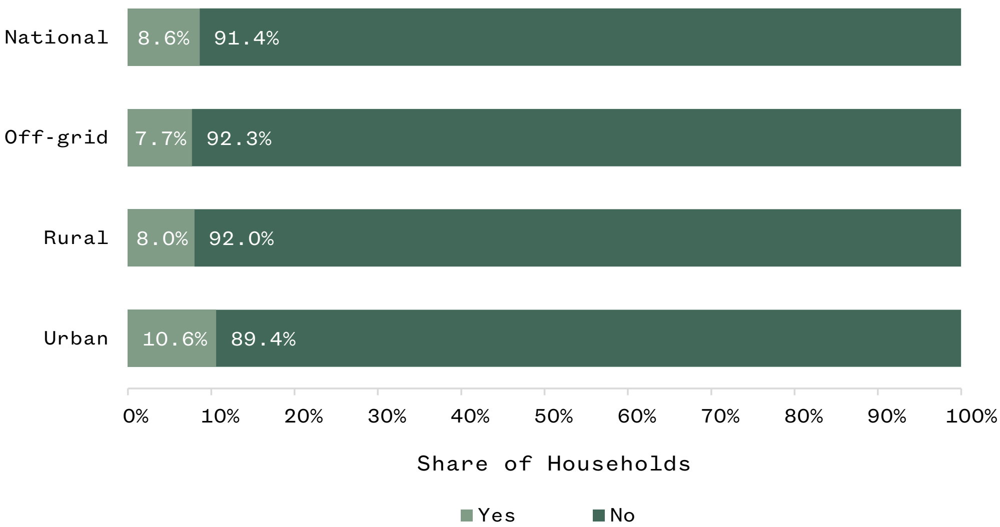
6.2 Consumer perspectives on quality

Level of service

Of all survey respondents with an off-grid solar appliance, 91% reported that the performance and level of service of appliance had not changed since the time of purchase. Only 9% registered a change in service level, and, of these, 38% reported that their service had deteriorated over time while 62% said service worsened during the rainy season.

Given the reduction in the solar resource, the authors of this study do not expect that solar appliances would provide the same level of service during rainy seasons. The survey data also included information on the age of the off-grid solar appliances and found that 20% of appliances were obtained before 2017 while 80% were bought in 2017 or later.

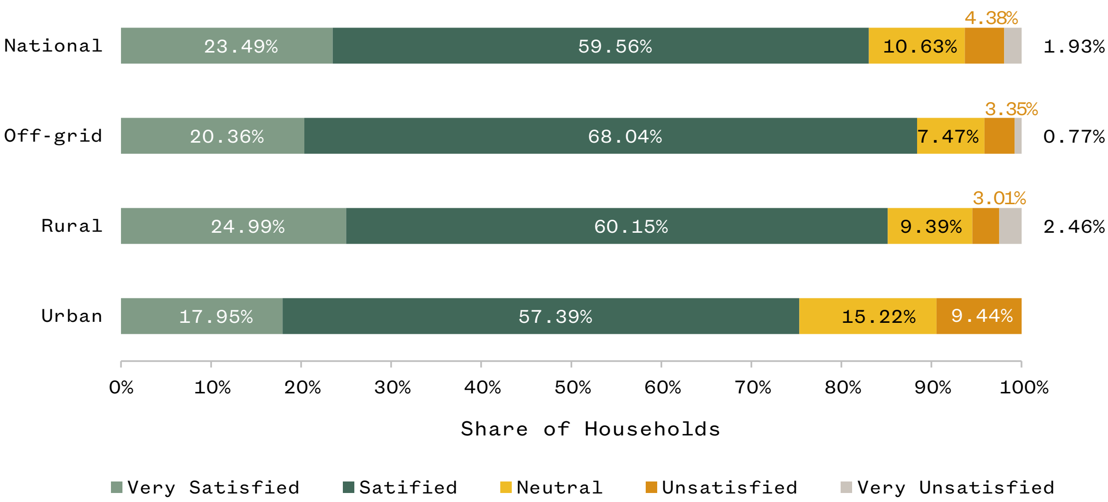
Figure 34: Appliance change in service level



Durability

Durability can be broadly described as the ability of a product to withstand wear, pressure or damage over a long time. Durable products have a longer lifespan whilst requiring little maintenance. This study assessed durability by asking survey respondents to indicate the frequency of breakage for their off-grid solar appliance. Results showed that only 12% of off-grid solar appliances owned by respondents had broken down since the time of purchase, 80% of which were appliances less than 4 years old (bought in 2017 or later), and 20% of which were more than 4 years old. Respondents also provided information on warranties. It was found that 71% of the off-grid solar appliances that had broken down were covered by warranty. Overall, analysis of survey data at a national level found that 60% of all respondents were satisfied with the durability of their off-grid solar appliance.

Figure 35: Level of satisfaction with durability of off-grid solar appliances

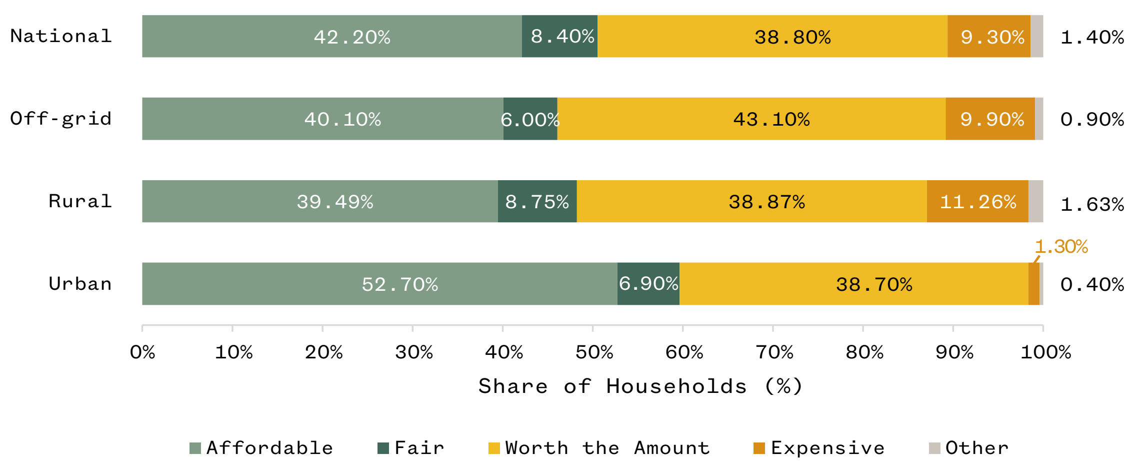


Affordability and accessibility

To assess affordability, respondents were asked to indicate the payment method used to acquire their off-grid solar product, the overall cost of the product, and their perception of its affordability. Overall, 42% of respondents reported that their off-grid solar appliances were affordable, with 59% expressing satisfaction with the overall product pricing. It is noted that most off-grid solar appliances, especially radios and televisions, are sold through pay-as-you-go sales models that distribute payments over an extended period through daily and monthly instalments. This likely contributes to consumer perceptions of affordability.

Accessibility was assessed by asking respondents the distance they would need to travel to purchase an off-grid solar appliance. On average, respondents indicated they would need to travel 15 km to purchase a solar television or radio. Solar water pumps were found to be the least accessible, as respondents said they would need to travel approximately 60 km, on average, to make a purchase.

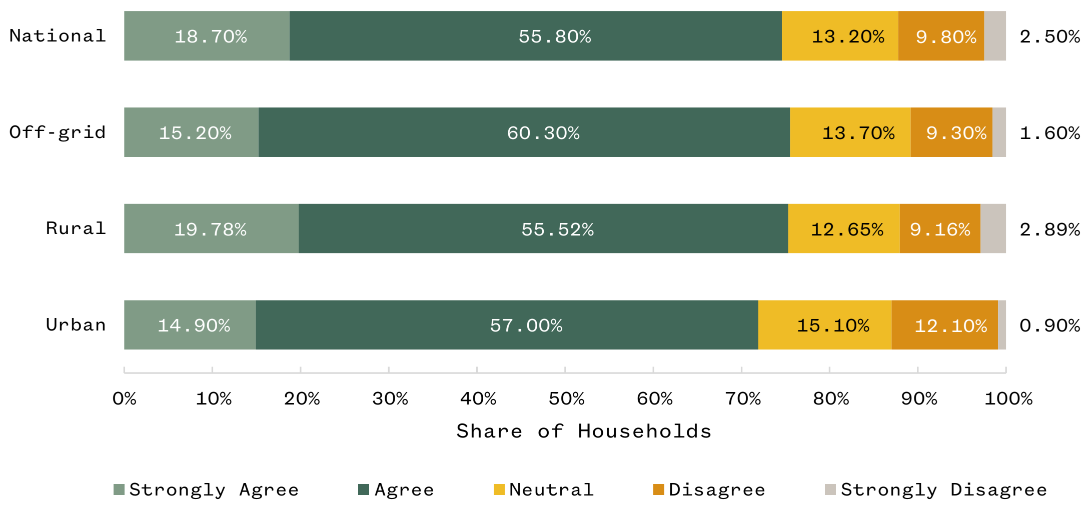
Figure 36: Perceptions on affordability of purchased off-grid solar appliances



Respondents were also asked to indicate ease of access to dealers and distributors. In this context, 56% of respondents agreed and 19% strongly agreed that it was easy to find dealers and distributors of their off-grid solar appliance, while 10% did not think this was the case. Rural households indicated disagreeing with ease of finding dealers and distributors more than urban households. This indicates there is a significant section of the market that has difficulty finding off-grid solar appliances.

There is also a likelihood that accessibility is perceived differently in the rural context compared to the urban context. For customers in economically advanced rural settings, traveling a few kilometres to reach a dealer might make them think that the appliances are relatively inaccessibility. In contrast, other rural dwellers who equally lack other services within reach a few kilometres might think that traveling this distance to a dealer might make the appliance seem accessible.

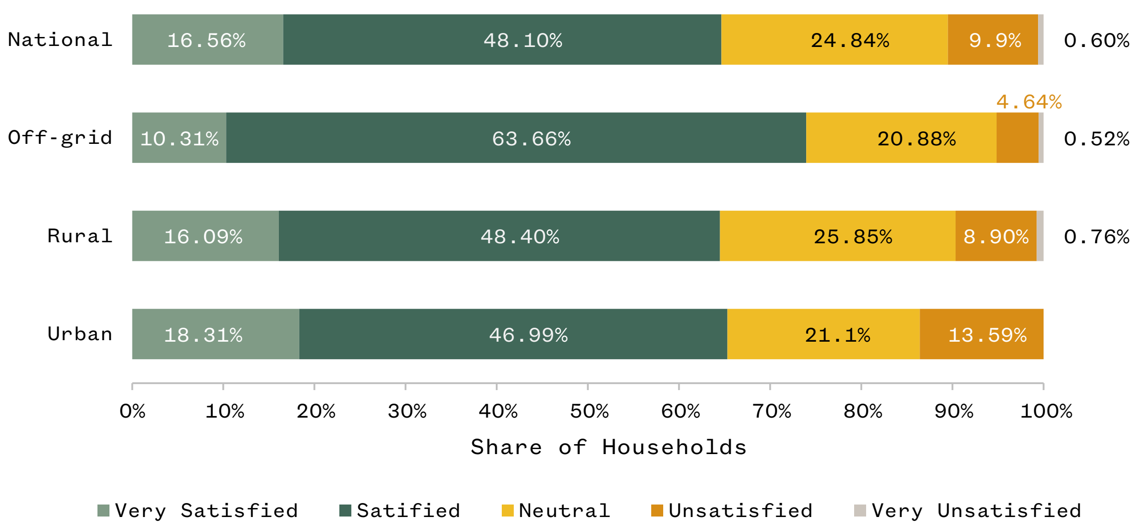
Figure 37: Perceptions on accessibility for off-grid solar appliances



After-sales services

The survey collected data on the level of satisfaction with after-sales services. Among respondents, 65% were either satisfied or very satisfied with after-sales support, while 25% were neutral and 10% were unsatisfied. Urban households reported more dissatisfaction (14%) than rural households (9%), which is a likely reflection on higher expectations especially on warranty.

Figure 38: Level of satisfaction with after-sales support for off-grid solar appliances

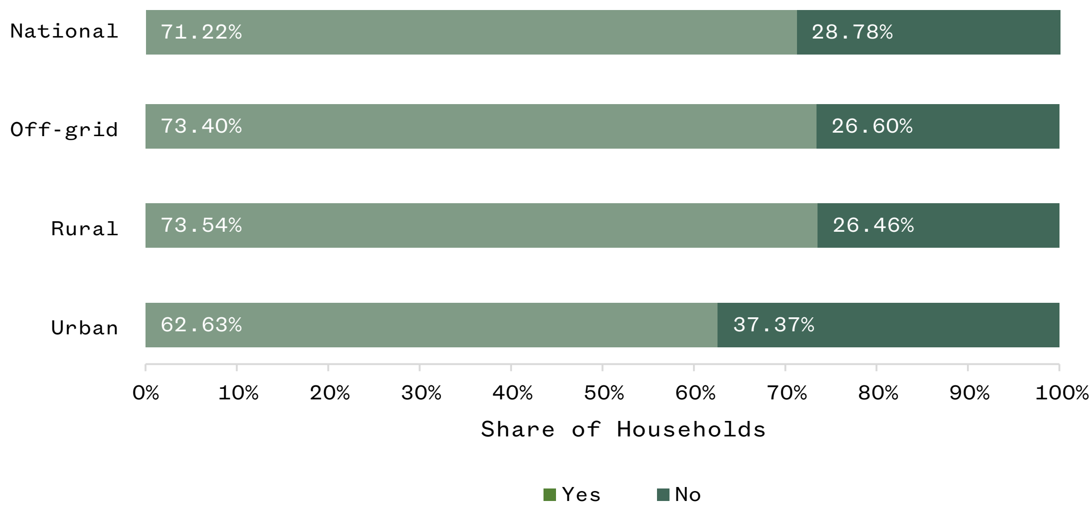


Warranty

Respondents were asked to provide information on warranty, and it was found that 71% of all the off-grid solar appliances covered in the survey had some form of warranty, while 29% had none or respondents did not ask at the time of purchase. The lack of warranty for 29% of off-grid solar appliances points to a significant gap in after-sale services, which can be attributed to the distribution models employed by manufacturers.

Most of these models rely on third-party distributors who may not have the incentive to follow-up with consumers after purchases are made or establish long-term relationships. The survey also found that where respondents indicated there was no warranty, 26% of urban households had requested for warranty compared to 7% of rural households. This also points to lower awareness of warranties among consumers in rural areas.

Figure 39: Product coverage by warranty for off-grid solar appliances



Respondents were asked to provide information on warranty claims, and it was found that, of the 71% of respondents who had indicated their off-grid solar appliance was covered by warranty, only 6% had made a warranty claim. This may indicate a low incidence of breakdown of the appliances. Of the respondents who had made a warranty claim, 69% of the claims were honoured and the appliance was either repaired or replaced.

Overall, 53% and 19% of respondents were satisfied or very satisfied with warranty services, respectively, while 19% and 9% were dissatisfied and very dissatisfied. This outcome, though not desired, is not entirely unexpected given that culpability on the part of the manufacturer can be difficult to prove on warranty claims.

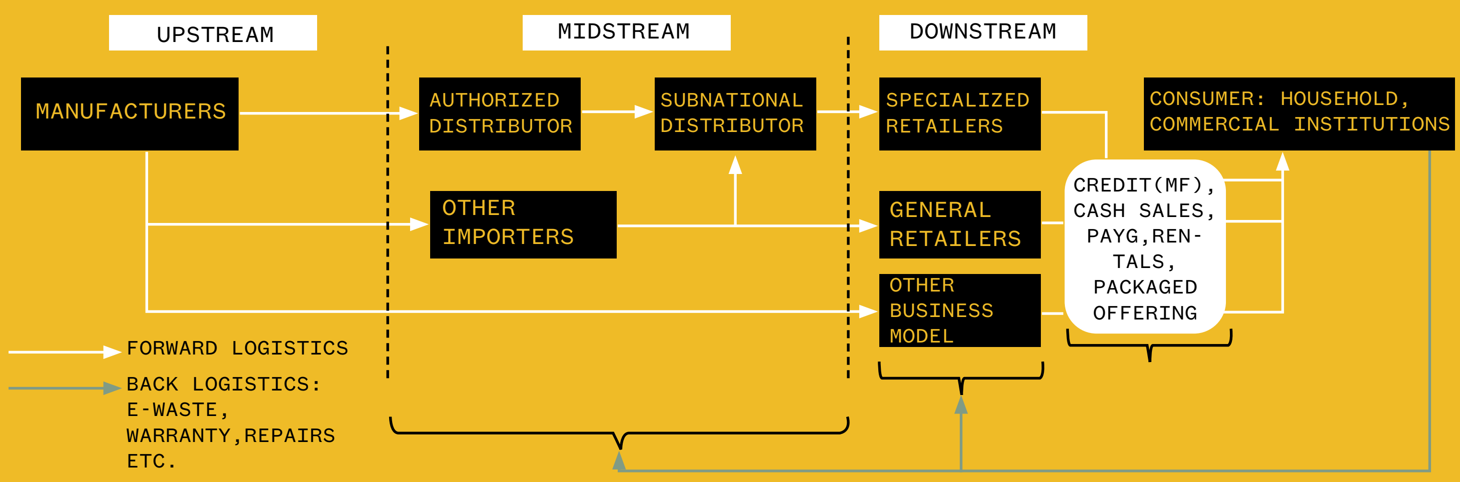
IT WAS FOUND THAT 71% OF ALL THE OFF-GRID SOLAR APPLIANCES COVERED IN THE SURVEY HAD SOME FORM OF WARRANTY, WHILE 29% HAD NONE

INSIGHT: **MARKET LEVERAGING IN PRODUCT DISTRIBUTION**

- Manufacturers using third-party distributors need to take measures to ensure that their customers can **access warranty** and **after-sale services**. This can be done by entering into partner or service agreements where the distributor honours a warranty and later claims it back from the manufacturer.
- **Service and maintenance** are also key in ensuring that consumers have their products repaired and serviced should the need arise.

In a key informant interview with a leading solar systems manufacturer and distributor, they indicated that some of their main selling points are that they have service centres across the country and that they operate a reverse logistics program to collect electronic waste (which can be difficult for consumers to dispose of). A typical distribution model employed by many mainstream solar companies is shown below.

Figure 40: Common distribution models employed by off-grid solar companies. *Source: EED Advisory*

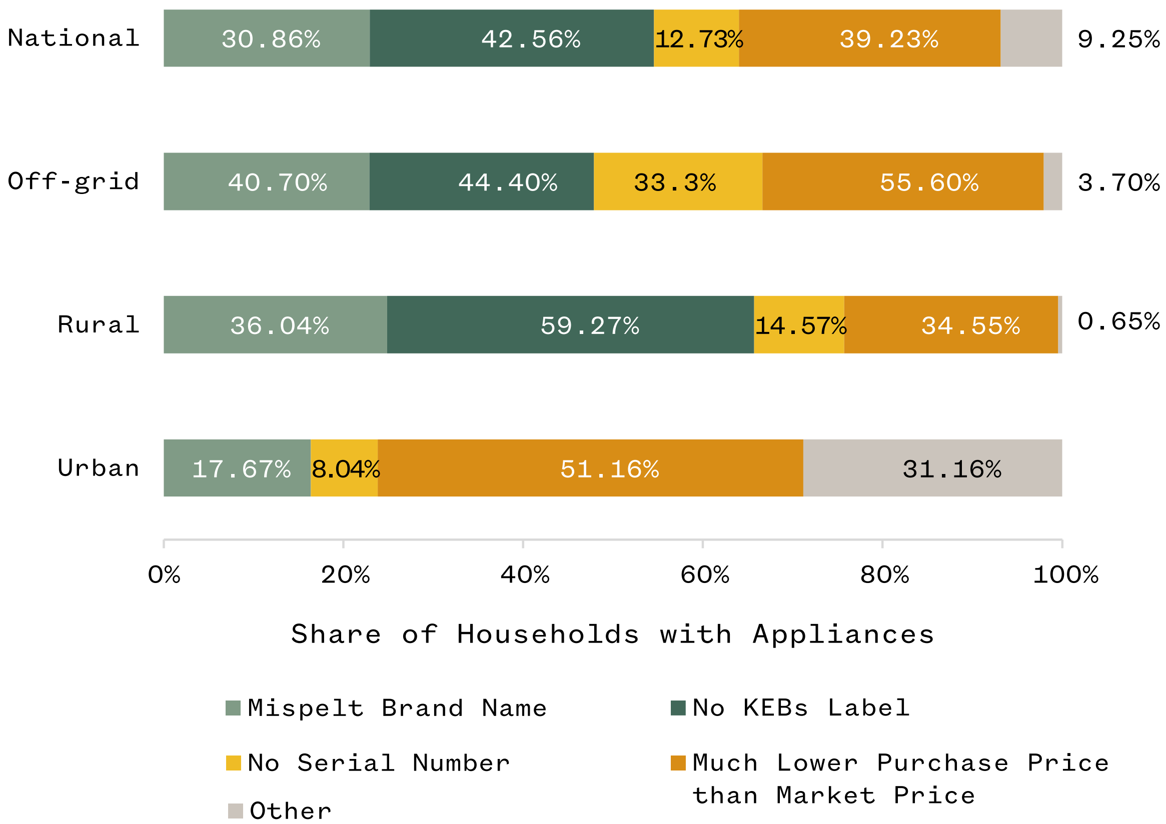


6.3 Substandard and counterfeit appliances

Survey results showed that 45% of respondents reported they had not encountered counterfeit or substandard off-grid solar appliances in the market. A similar proportion of respondents, however, indicated they were not aware what counterfeit or substandard products were, with only 10% of respondents indicating knowledge about counterfeit products. From among those surveyed, 17% of respondents reported having used a counterfeit or substandard off-grid solar appliance. Respondents who could identify counterfeits reported identifiers included misspelt brand names (31%), lack of Kenya Bureau of Standards labelling (42%), and the lack of a serial number (12%).

Figure 41 suggests that the respondents from urban households may have different perceptions of quality compared to respondents from rural households. It is likely that urban dwellers have more exposure to information and unethical market dynamics. Urban dwellers may, for example, pay less attention to Kenya Bureau of Standards labelling if they are aware of this symbol being misused.

Figure 41: Identifiers of counterfeit or substandard products in the off-grid solar appliance sector in Kenya

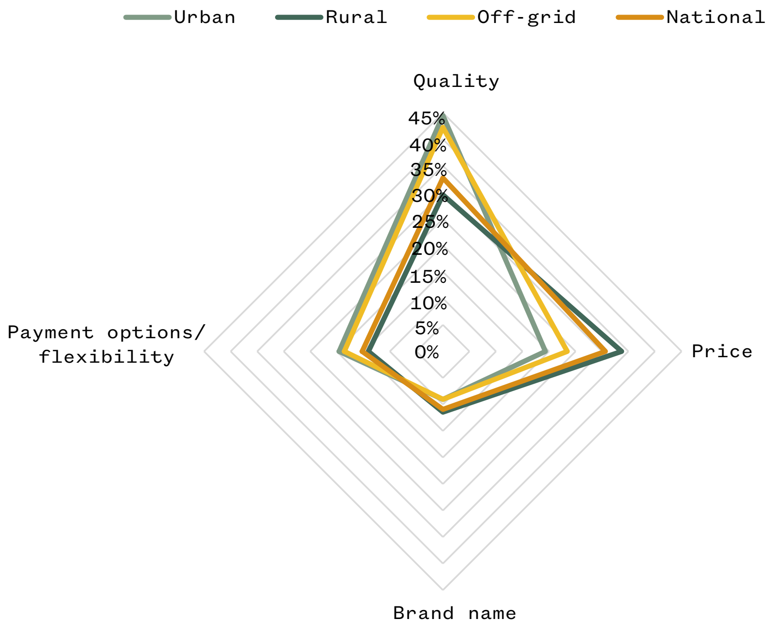


6.4 Factors influencing purchasing decisions

Respondents were asked to indicate their primary and secondary considerations when deciding to purchase their off-grid solar appliance. In this context, 33% of respondents indicated that quality was their main consideration, followed by price. A similar proportion of respondents indicated that price was their primary consideration followed by quality. It is therefore evident that quality and price are the two significant and competing variables respondents consider when deciding to purchase an off-grid solar appliance.

While price is a measurable and objective variable, quality is subjective and may vary from one consumer to another based on experience and preference. The survey found that consumers define quality differently from regulators, for example. Respondents reported relying on friends and family who have used the product, brand recognition, and/or visual inspection to access quality. Figure 42 summarises how respondents rated the influences on their purchasing decision.

Figure 42: Main consideration when purchasing a solar appliance



07 Conclusions

This study developed a survey to better understand the off-grid solar market in Kenya from a consumer perspective. Survey responses were assessed across quality verification status, across national, rural, urban and county levels, and across off-grid solar product and appliance types. The study confined itself to assessing the consumer experience at the household level. The off-grid solar products surveyed were solar lanterns, solar lighting systems and solar home systems, while off-grid solar appliances included radios, televisions, fridges, fans and water pumps. It is noted that mobile phones were not within the scope of this study. The following discussion presents the conclusions of this study in the form of insights and key findings.

Consumer Experience with Solar Energy Kits

Overall, about 80% of all consumers reported being either satisfied or very satisfied with the solar energy kit. Similarly, 76.5% of consumers are satisfied with the durability of their solar products. The majority of the consumers (73.6%) also reported either being satisfied or very satisfied with the pricing of their solar product, and 72.2% were satisfied with the after-sales services received. Most consumers are satisfied with the service offered by the solar product, and, when factoring in issues such as pricing and after-sales services, the consumers are satisfied with the service offerings of manufacturers and distributors.

The off-grid solar market is growing in areas with grid supply

Off-grid solar technology was by definition initially targeted at areas not served by the grid. This study has however found that off-grid solar products and appliances play a prominent role in grid-connected areas. A significant share of grid-connected households use off-grid solar products as their main or secondary source of lighting. In Migori County, close to half of the households connected to the grid use off-grid solar products as their main source of lighting. While this study did not set out to investigate the quality of electricity supply from the grid, it is evident that in many areas a low quality of supply has compelled users to seek alternative sources. Issues may include the frequency and duration of supply interruptions and voltage fluctuations. Off-grid solar product distributors appear to be aware of this market opportunity, as sales in urban areas across the country are a significant proportion of overall market share.

Perceived quality and price are leading determinants of consumer purchasing decisions

This study found that consumers make decisions to purchase off-grid solar products primarily on the basis of quality and price. In the study, quality was defined to include inherent design and supporting services such as warranty and after-sales service. Brand names, which are intricately linked to perceptions of quality, were found to be the third most important determinant of choice. The study observed that the presence of financing incentives, after-sales support, distribution and marketing channels of certain brands contribute to product association with quality. The existence of counterfeit products that look similar or have similar names to these brands confirms this association.

Price was found to play a different influencing role based on the type of off-grid solar product being considered. Survey respondents who owned more expensive products, namely solar lighting systems and solar home systems, were attracted equally and in some cases more by the payment option than the price. Less than one in three solar lighting systems and solar home systems were purchased with cash paid up front.

Off-grid solar lanterns, which are significantly more affordable, were mostly purchased through up-front cash payments. Respondents who owned off-grid solar appliances also showed variation in how they related to price. Less than half of these respondents viewed their appliance as being affordable.

Most off-grid solar product breakdowns are associated with batteries

This study found that breakdown of off-grid solar products and appliances was most commonly associated with battery issues. When respondents were asked which component was associated with malfunctions, breakages or failures, close to one in every two respondents owning a solar lighting or solar home system identified the battery as the source of the problem. It appears that a focus on improving batteries, including the type, design, configuration and position in systems, will improve the overall performance of off-grid solar products. The next most common component associated with product breakdown was the switch.

Quality-verified off-grid solar products deliver expected services to consumers

This study confirms that quality-verified off-grid solar products are rated positively by consumers. Seven out of every ten owners of off-grid solar products reported being satisfied or very satisfied with their product on measures of durability, pricing, performance and overall satisfaction. Four out of every five respondents who owned a quality-verified solar lighting system or a solar home system reported having received a warranty for their product.

Respondents who owned a quality-verified solar lantern showed different results on warranty and after-sales services. Half of these respondents had a warranty for their quality-verified solar lantern, but in general owners of quality-verified solar lanterns indicated lower expectations for after-sales support.

Possible reasons for this are:

- Solar lanterns cost significantly less than solar lighting systems and solar home systems.
- Many channels and distributors are involved in retailing solar lanterns.
- Due to their affordability, there is a higher incidence of one-time purchases and cash payments, and therefore lower motivation for sellers to guarantee quality.

An unexpected finding of this study was that non-quality verified off-grid solar products also achieved positive ratings from consumers, although in assessments of quality and durability, quality-verified products still rated significantly higher than non-quality verified products. Further comparison on the basis of quality verification found that:

- Survey respondents with quality-verified and non-quality verified solar lanterns and solar home systems were equally satisfied with the durability of their products. In contrast, 77% of respondents with quality-verified solar lighting systems expressed slightly higher satisfaction with their product compared to 72% of respondents with non-quality verified solar lighting systems.

- A significantly higher proportion of non-quality verified off-grid solar lanterns (19%), and solar home systems (31.3%), were reported to have broken down compared to quality verified lanterns (9.2%), and solar home systems (8.9%). This may be the likely reason why a significantly higher proportion of respondents with non-quality verified off-grid solar lanterns were less likely to recommend the product. For lanterns, the study also notes that the cost of repair or replacing the product is higher for non-quality verified lanterns when compared to quality-verified lanterns.

- A significantly higher proportion of respondents with quality-verified solar lanterns (52.5%), quality-verified solar lighting systems (79.3%) reported having received a warranty compared to respondents with non-quality verified solar lanterns (36.5%), non-quality verified solar lighting systems (52.0%)

Quality assurance processes are yet to be developed for off-grid solar appliances. This study however found satisfaction with these appliances, with four out of five respondents who owned an off-grid solar appliance rating the durability of the appliance positively.

Radios and televisions dominate market share in the off-grid solar appliance market

This study found that the off-grid solar appliance market is overwhelmingly dominated by radios and televisions, which constitute 95% of total market share.

Similarly, most respondents who reported an intention to purchase an off-grid solar appliance, regardless of whether they lived in urban or rural areas, mentioned radios and televisions. This confirms the already well-documented potential of the off-grid solar sector to evolve beyond lighting and phone charging, and also beyond serving off-grid areas only. With the continued decline of prices for solar technology, increased research on battery storage, increased efficiency of off-grid solar appliances, and responsive financing solutions, it is expected that more off-grid solar appliances will become affordable to households.

Households who currently own off-grid solar powered fridges were found to select this appliance despite connection to the grid. Survey responses showed that there are about the same number of off-grid solar fridges in urban areas (51% of national reported ownership) as in rural areas (49% of national reported ownership), despite urban areas having higher grid connection rates compared to rural areas. The disparity is even more pronounced when considering that only 31% of the Kenyan population reside in urban areas. Factors at play may be a low quality of service from the grid, and an increasingly sophisticated financing, distribution and marketing system within the off-grid solar market. Mobile phones and the ability to charge them are also a likely driver of growth for the off-grid solar market, but this was not explored as part of this study.

Consumers perceive brand as a strong predictor of quality

This study categorized off-grid solar products based on brand as part of identifying quality verification status. A data set based on product brand was therefore available.

The study defined affiliated brands as brands that have at least one of their products quality verified under the Lighting Global Quality Assurance framework (now called VeraSol). When the entire survey sample was grouped into two categories, affiliated brands and non-affiliated brands, the following observations were made:

- Most **products fell under the affiliated brands** group.
- While nearly **four in every five** consumers with affiliated brand products reported being satisfied with their products, only **two out of three** consumers with non-affiliated brand products reported the same.
- **8% of consumers** with affiliated brand products reported being unsatisfied with their product, compared to nearly double the number of consumers **(15%)** with non-affiliated brand products.
- **Two out of every three consumers** with affiliated brand products reported having a warranty (including owners of off-grid solar lanterns), compared to just over **one in three consumers** with non-affiliated brand products.

These observations show that distinctions in performance and quality are heightened when products are compared based on brand affiliation. The following insight explores branding and its important role in the Kenyan off-grid solar market.

INSIGHT: **THE POWER OF BRAND NAMES IN THE OFF-GRID SOLAR SECTOR**

A brand can be defined as a **product's association with a manufacturer's label**.

Many firms that distribute quality-verified products also sell non-quality verified products. Off-grid solar products sold by affiliate brands contribute a significant proportion of non-quality verified products and yet benefit from the same process, marketing and distribution efforts.

Firms focus on the quality of their overall brand. There are four main factors that make brand a strong predictor of quality in the Kenyan off-grid solar market; brand integrity, warranty offerings, other certification schemes, and the flexible pay-as-you-go (PAYGO) payment model (Figure 43). Affiliated brands invest significantly in building a reputation with consumers and, therefore, have an inherent motivation to maintain acceptable standards regardless of the quality-verification status of their products. It would be self-defeating for a firm that sells quality-verified products to have significantly different standards for its non-quality verified products.

Figure 43: Predictors of brand strength in off-grid solar

The result is that affiliated brands develop non-quality verified products that could likely meet minimum acceptable standards to maintain brand competitiveness. Offering warranties further compels firms to deliver quality products, whether verified or not, to minimize the cost of after-sales support. Affiliated brands are also likely to be selling their products in multiple countries, each of which may have their own approach to quality and certification, creating more incentive for these firms to develop products that can meet a range of requirements. Finally, offering payment options such as PAYGO means that consumers will inevitably have a long-term relationship with the brand. This again provides reason to ensure products work well.

Brand as a driver of demand

The Lighting Global Quality Assurance framework attracts firms on the basis that quality verification enables off-grid solar products to gain market entry or expand market share. Quality verification may also achieve these goals through associated benefits such as access to market intelligence, business-to-business linkages and access to finance. This study did not find evidence that quality-verified off-grid solar products attract greater retail consumer demand compared to non-quality verified products, simply on the basis of verification. This finding is expected. The Lighting Global Quality Assurance framework was not designed as a consumer-facing initiative to result in demand-pull, but rather as an up- and mid-stream initiative to ensure supply-push of quality products. Consumers are therefore more aware of brand as a product differentiator compared to quality-verification status. About 20% of the off-grid solar products surveyed in this study were non-quality verified products, but few respondents reported being aware of counterfeit products.

Firms that manufacture and distribute quality-verified products are also those that have well-developed distribution and marketing infrastructure. It is these factors, rather than quality verification, that promote a firm's products. This assertion is further confirmed by the prevalence of affiliated off-grid solar products which constitute 90% of the products owned by survey respondents. Data comparison also found no statistically significant difference in the reported distance to acquire quality-verified off-grid solar products compared to non-quality verified ones, but affiliated brand off-grid solar products were reported to be closer to respondents than non-affiliated brand ones, further suggesting well-developed distribution networks and a longer-term marketing approach.

Solar lanterns and off-grid solar appliances are distinct asset classes relative to solar lighting systems and solar home systems

There is a need to differentiate solar lanterns and off-grid solar appliances to ensure that research and analysis is representative. Solar lanterns are compact, have fewer movable parts, and have simpler designs than solar lighting systems and solar home systems. The lanterns also cost significantly less and are often purchased with an upfront cash payment. They also appear to achieve higher unit sales despite lower levels of commitment to after-sales support.

The product range, price, design and operation of off-grid solar appliances is markedly different from solar lighting systems and solar home systems, more so for products such as solar pumps and solar fans. These differences play a role in how to correctly define metrics for quality assessment. For example, battery type and design are a key determinant of quality for a solar home system. For an off-grid solar water pump, the battery coupled with features of the pump and characteristics of the water source all determine the quality of the final product.

The range of complexity and the associated consumer perception of quality for solar lanterns and appliances should be taken into account when developing and implementing quality standards.

08 Recommendations

Develop firm-level quality verification methods and standards

The Lighting Global Quality Assurance framework (now VeraSol) provides a process for quality verification at the product level. The conclusions of this study highlight that consumers have a low awareness of quality-verification status and that brand is the more likely driver of demand. There is an opportunity to leverage how consumers associate with brands in the off-grid solar market to further develop and implement quality assurance. This study recommends exploring firm-level quality verification methods and standards to complement product-level verification. An insights discussion is provided in the following sections to define such an approach and consider its benefits and challenges.

Firm-level verification could be a light-touch option which may encourage more firms to join the VeraSol quality verification process. The need for such a framework is heightened by the increasing number of off-grid solar appliances which, under a product-based approach, would require individual standards. Developing standards for solar lanterns, solar lighting systems and solar home systems is a complex process, but the diversity of off-grid solar appliances compounds this further and starts to erode the merits of a product-based approach. As mentioned, the success of an off-grid solar water pumping system, for example, is not only dependent on the power unit but also on the design of additional components and infrastructure. It is difficult to standardize a system with multiple and varying components. It is noted that restricting quality assurance to the power system adds marginal value to consumers who are unlikely to be able to distinguish the quality or contribution of constituent parts.

The Lighting Global Quality Assurance framework and initiatives such as Lighting Africa have served the off-grid solar market well in providing a benchmark. More sophistication is now needed in a market where there is proven demand for products and experience with and incentive for maintaining minimum standards. Consumers have benefited from the Lighting Global Quality Assurance framework as manufactures adhere to these standards while exploring new markets. Firm-level verification can offer an all-encompassing validation for firms whose processes and policies meet a minimum acceptable standard. This type of overarching approach is likely to be attractive to many firms as the outcome of one process would benefit their entire product portfolio.

INSIGHT: **FIRM-LEVEL QUALITY VERIFICATION**

Firm-level verification can be defined as an all-encompassing **mark of validation for firms** whose processes and policies meet a given minimum acceptable standard.

Such a process would be independent of product-level verification. The structure and content of a firm-level verification framework would need to be developed in close consultation with regulators, industry associations such as GOGLA, the Global Association for the Off-Grid Solar Energy Industry, and the Kenya Renewable Energy Association, off-grid solar product and appliance manufacturers, and independent standards bodies such as VeraSol. Adopting a collaborative approach would not only provide third-party validation, it would also enable firms to continually measure, re-evaluate and improve their production systems to ensure quality and reliability.

The benefits of firm-level verification include:

- **A higher likelihood of more firms adopting the process.** A quality-assurance approach that benefits an entire product portfolio would be attractive to firms. The risk of firms mixing low-quality products with high-quality products is diminished by the motivation to uphold brand integrity and maintain competitiveness.

- **More flexibility.** There is an opportunity to overcome barriers that have been created where product-level verification is adopted or modified in a way that constrains markets, for example by limiting the range of products that can be offered. With the additional option of firm-level verification, firms can chose to adopt product verification only, firm verification only, or both.

Likely challenges with a firm-level verification approach include:

- Firms may find that the costs of pursuing both firm-level and product-level verification are limiting.

- Independent standards bodies and regulators may find that the scope to incorporate relevant partners and processes to develop a firm-level verification process is limiting, especially given that some regulators are already pursuing a product-level verification approach.

The International Organization for Standardization (ISO) ISO 9000 family of standards is an example of a comparable firm-level framework (Figure 44). Like product-level verification, firm-level verification should be renewed after a standard period of time and strengthened by impromptu spot checks.

Figure 44: An overview of the International Organization for Standardisation (ISO) ISO 9000 process

Develop a VeraSol seal supported by text messaging authentication

As has been discussed, this study finds no evidence that consumer demand for quality verified off-grid solar products is driven by an understanding or awareness of quality verification, whether through Lighting Global or VeraSol. Demand for quality verified products is driven rather by the measures firms take to promote and distribute their products. Consumers have therefore no objective method of rating the quality of off-grid solar products and appliances.

The idea of developing a seal for the Lighting Global program has been discussed extensively over the years. A VeraSol seal would provide assurance to consumers on the quality of their product from an independent perspective. A VeraSol seal is also likely to encourage non-quality verified off-grid solar product or appliance manufacturers to seek verification as their products or appliances would conspicuously be missing a quality symbol. It is noted that the impact of a quality seal on sales may differ based on the product in question. Solar lanterns, for example, are relatively cheap and tend to appeal to one-time sellers who have no intention of developing longer-term relationships with purchasers. In contrast, the rise in sales of off-grid solar appliances, which require a relatively higher financial commitment from consumers, justifies the need to provide some level of comfort to purchasers.

Seals have been successful in other contexts. Examples include the Energy Star energy efficiency rating system, Eurovent Certification for air quality and ventilation systems and the Technischer Überwachungsverein (TUV) Certification for product and equipment safety (Figure 45). It is noted that these seals have been deployed in markets with relatively strong consumer protection institutional and legal frameworks compared to many of the markets where off-grid solar products are sold.

Figure 45: Examples of quality seal labels

DEMAND FOR QUALITY VERIFIED PRODUCTS IS DRIVEN BY THE MEASURES FIRMS TAKE TO PROMOTE AND DISTRIBUTE THEIR PRODUCTS RATHER THAN A CUSTOMER AWARENESS OF QUALITY VERIFICATION.

In the off-grid solar market, challenges to adopting a quality seal may include the need to translate the seal to local languages, risks of counterfeiting, and the significant resources required to raise awareness and popularize the seal. Local experiences have produced mixed results. For example, prevalent counterfeiting has reduced the value of the Kenya Bureau of Standards (KEBS) mark of quality.

This study recommends that VeraSol consider a language-agnostic seal that can be authenticated by sending a serial number to a free text message service. This approach would help to ensure that quality-verified off-grid solar products are easily distinguishable by consumers. A seal could be the missing link enabling off-grid solar consumers to associate a standards mark with quality verification. There is an industry precedence that when a mark becomes synonymous with quality, more manufactures are incentivised to adopt it.

Differentiate quality verification for off-grid solar lanterns and off-grid solar appliances

Solar lanterns and off-grid solar appliances fall on opposite sides of the complexity spectrum. While lanterns are relatively easier to design and assemble, appliances may have many electrical and mechanical parts. The solar lantern market is highly competitive and with modest returns relative to solar lighting systems and solar home systems. Financial incentives for servicing a lantern in the event of failure are minimal. For example, the cost of transporting and repairing a solar lantern is often comparable to the cost of buying a new one.

Solar lanterns tend to appeal to uncommitted one-time sellers, and adopting quality assurance standards for this product is difficult and unattractive to manufacturers. From the consumer's perspective, this study found no discernible difference in the perception of quality for quality-verified and non-quality verified solar lanterns. This is in part because the product is smaller, simpler and has few points of failure.

Evaluating the quality of off-grid solar appliances, on the other hand, is a complex task involving the functionality and design of multiple components. In some cases, for example solar fridges and water pumps, these components may not be sold as one unit, and may be sourced from varying international and local distributors.

Installers of solar appliances can take liberties in purchasing decisions and complete the unit as they see fit. All these factors need to be considered in developing a quality assurance framework for off-grid solar appliances.

This study recommends a differentiated quality verification schedule for solar lanterns and a differentiated schedule for off-grid solar appliances. It is, however, re-stated that developing a suite of standards for all possible off-grid solar products and appliances may be a challenging task whose costs are likely to outweigh the benefits.

Facilitate partnerships between affiliate brands and last-mile distributors

Affiliate brands invest heavily in strengthening last-mile distribution networks. These brands have slowly divested from vertically integrated models and expanded partnerships with local traders to reduce the high cost of distribution. Three out of every four surveyed respondents with quality-verified off-grid solar products reported purchasing their product at an authorized dealer or from a local distributor who brought the product to the respondent's home. These partnerships were found to be an important connection to warranty services. Only one in three respondents who purchased their off-grid solar product at a local electrician shop reported having received a warranty, compared to five in every eight whose purchase was made from a last-mile distributor delivery to the respondent's home.

This study also found that distributors and dealers are the second channels of information for consumers, after recommendations from family and friends. At least one in three respondents who owned a quality-verified off-grid solar product, and one in four with a non-quality verified product, heard about the product from a last-mile distributor. Given the level of influence last-mile distributors have on consumers, a programme focused on their engagement is recommended. Such a program would aim to:

- Facilitate partnerships between affiliate brands and local distributors in new markets.
- Promote awareness on quality to ensure distributors can adequately communicate the differences and the benefits of products and associated services, for example warranty.

Unbundle the definition of off-grid solar appliances

This study found that televisions and radios overwhelmingly constitute the majority of off-grid solar appliances. Assessment of survey results was therefore heavily skewed towards televisions and radios. Unbundling the industry term 'off-grid appliances' would enable better consideration of off-grid solar appliances that are not televisions or radios. This new group includes appliances that are typically more complicated in design. An option would be to re-

classify off-grid solar appliances into domestic appliances (televisions, radios, electric pressure cookers, fans and other appliances used at the household level) and productive appliances (water pumps and other non-domestic appliances). Such a classification will ensure under-represented off-grid solar appliances are also captured in initiatives to grow their market share.

Research further and standardize tracking methods

The off-grid solar market in East Africa is advanced compared to many regions globally. There is a need to adopt a standardized approach across new and advanced markets to track the progress of market growth. This includes how aspects like prevalence rates, quality, affordability, accessibility and consumer awareness are defined and measured. A common approach to assessing the off-grid solar sector will assist in innovation efficiency and like-for-like comparisons in lessons learned. This study, for example, should be replicated in Kenya after several years to track changes against interventions while at the same time offering a template for similar studies in other markets. Further and more specific research is also needed on off-grid solar appliances with more representative sampling methodology. The perspectives of distributors could be a useful entry point for such a study. Better research on off-grid solar appliances is crucial and should precede the development of standards for these appliances.

Adopt more representative research to capture features that are unique to the off-grid solar market

A key learning from the surveying methodology developed for this study was that identifying brand model descriptions while in the field can be a challenge.

This has been discussed as a limitation in the study. It is recommended that future research initiatives that adopt a similar approach as this study take the following actions:

- **Train data collection team or enumerators to focus on the top ten products in the market.** Enumerators should be well-versed with the different major brands and where to locate the brand model on each device.

- **Clarify training on photography with a preference for capturing the entire product.** Of the 1,414 respondents in this study, only 45.6% were comfortable with an image of their product being captured. Though the initial purpose of photography was to capture the serial number, it would have been more beneficial to capture the entire product which can be better recognized and classified.

- Consider the definition of classification categories. This study classified products as quality-verified or non-quality verified based on the Lighting Global/VeraSol Quality Assurance framework. Survey responses however showed this excluded products that may meet standards through other processes, such as through the Kenya Bureau of Standards (KEBS) or through certificates of conformity that determine that products meet International Electrotechnical Commission (IEC) standards standards based on testing at international labs that are not part of VeraSol but are recognized by the state based on meeting appropriate accreditation requirements. A better approach may have been to classify products under likely types of certification, for example, 'VeraSol Certified', or 'KEBS standard adopted' or 'No certification'.

- **Note and account for errors** that may be caused by survey questions that rely on respondent memory, for example the date of purchase of a product.

- **Note and account for the fact that off-grid solar appliances are a separate class**, and random household selection may not provide a sufficient sample size.

A mixed method study approach would also be useful for future study design. Studies that involve a more varied set of methods (that is, going beyond surveys) can create data sets that are more informative. Additional methods may include focus groups, text message or phone-based studies, and laboratory or field testing.

09 Annexes

Detailed description of survey methodology

Data collection strategy

A three-step approach was adopted to collect and collate data. This included: **(i) Desk Review; (ii) Field Data Collection; and (iii) Data Synthesis and Reporting** as shown below.

Project approach

INCEPTION AND DESK REVIEW

- Literature review on prevelance of off-grid appliances
- Finalise the sampling frame and sampling strategy
- Finalise the data collection tools
- Stakeholder identification
- Develop training manual
- Code questionnaire
- Pre-testing survey
- Revision of survey tools
- Inception report

FIELD DATA COLLECTION

- Recruitment and training of field personnel
- Household survey
- Key informant interviews
- Raw and cleansed dataset

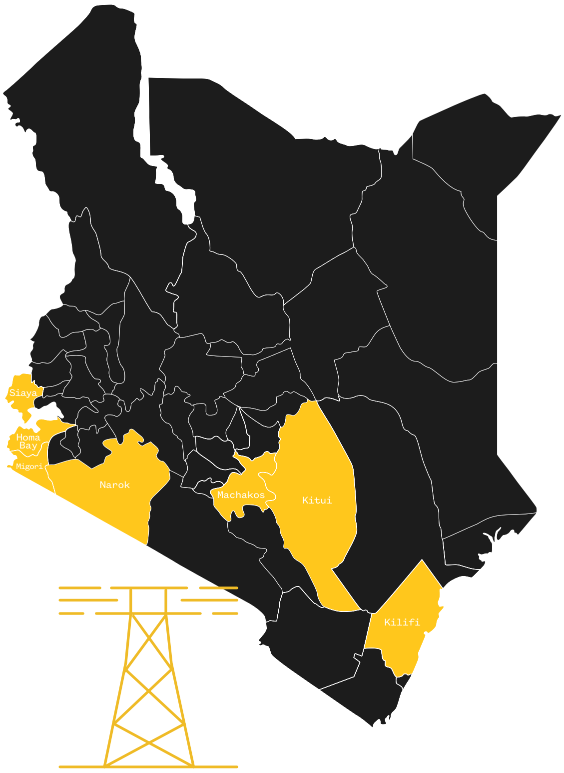
DATA SYNTHESIS AND REPORTING

- Data analysis
- Draft Report
- Final Report
- Dissemination of findings

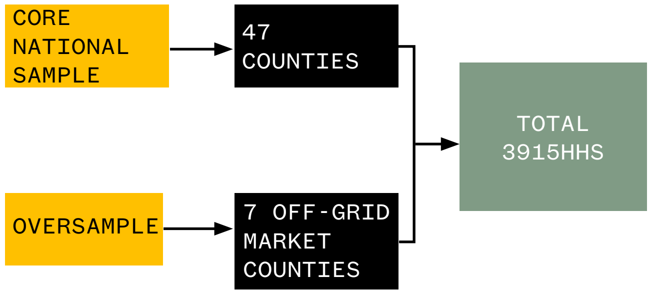
Sampling strategy

Based on the requirements of the Terms of Reference (TOR) and following discussions with the CLASP Team, the sample frame was representative of the national prevalence of solar products and representative of the prevalence of solar products for off-grid markets. The total sample size, 3915 households (HHs), was therefore selected proportionally from the 47 counties and combined with oversampling in 7 counties representing the off-grid markets.

Off-grid markets were defined as counties that meet two criteria: i) the prevalence of solar lighting products was above the national median reported in the Kenya Population Housing Census (2019) and ii) the sales of solar TVs were above the average reported in Global LEAP Results-Based Financing (RBF) sales data for Kenya.



Sampling Frame



Notes

- **22 counties** met the criteria for off-grid markets. **7** of these counties were selected to represent the off-grid segment.
- The **7 oversampled counties** included **Homa Bay, Siaya, Narok, Kilifi, Kitui, Migori and Machakos**.
- **2** of the counties, **Kilifi and Narok**, are ear-marked as KOSAP counties.

Sample Size Calculation

The sample size formula developed by Cochran[94] for cross-sectional studies for population proportions was used to compute the sample size for each county, with target power of 80% and 95% level of confidence, adjusted for 10% non-response and design effect. Note that Finite Population Correction (FPC) was applied to the sample size formula to adjust variance estimate because the sampling is without replacement.[95] However, when the population size is above 100, 000, the sample size does not change much when FPC is applied.[96]

$$n = \left(\frac{\frac{Z_{\frac{\alpha}{2}}^{2} p(1-p)}{e^{2}} * N}{\frac{Z_{\frac{\alpha}{2}}^{2} p(1-p)}{e^{2}} + (N-1)} \right) kf$$

SYMBOL	VALUE	DESCRIPTION
	1.96	The critical value of the normal distribution at . At a 95% level of confidence, and the critical value is 1.96.
p	0.5	Conservative prevalence of the indicator of interest
f	1.18	Sample design effect. It represents how much larger the squared standard error of a two-stage sample is when compared with the squared standard error of a simple random sample of the same size. The sample design effect is defined as: $f = 1 + \rho\,(m - 1)$.
m	7	The average number of households selected per EA
ρ	0.03	Intra-cluster correlation coefficient. It is a number that measures the tendency of households within the same Primary Sampling Unit (PSU) to behave alike concerning the variable of interest.
k	1.05	Factor accounting for non-response (assume 5%)
	5%	The margin of error (5% is standard)
n	varies	Sample size in terms of the number of households to be selected. (Different for each county)
N	varies	Household population size (Different for each county)

Selection of respondents

A two-stage cluster sampling strategy was used to select households, the approach is the most efficient for large-scale surveys. First, the Enumerations Areas (EAs, also called Primary Sampling Units, or PSUs, or clusters) were selected randomly across the 47 counties. The PSUs were generated based on a spatial algorithm developed by EED Advisory, associates from the National Autonomous University of Mexico (UNAM) and Stockholm Environment Institute (SEI). The algorithm defines discrete population enumeration areas bounded by Kenya's 7,149 sub-locations. Each enumeration area contains roughly 200 households or 1,000 people. The enumeration areas were then selected using a two-tier stratification plan. The stratification was by county and rural/urban residence:

- **County:** HH selection for the core and off-grid markets was proportional to each County's population based on the 2019 census.
- **Rural-Urban:** Counties were divided into rural and urban areas based on the definition of urban and rural from the 2019 census. This resulted in a 70:30 rural to urban split at the national level.

Second, the households were then randomly selected (Secondary Sampling Units, or SSUs) from the PSUs determined in the first stage. The sampling technique for both PSUs and SSUs is simple random sampling without replacement (SRSWOR). The distribution of PSUs was done in a manner that maximizes differences between households within a PSU and minimizes the differences between PSUs. Simply put, the intra-cluster correlation is ideally close to zero. Additionally, studies[97,98] have shown that for constant overall sample size, increasing the number of PSUs increases statistical power faster than increasing the number of SSUs, because the former results in uniform distribution and saturation of SSUs over the sampling space, in this case, an entire county.

Respondent identification

For respondent identification, a spatial-based household listing approach was adopted. The approach used a publicly available high-resolution (30M or 1 arc-second) population distribution mapping of Kenya developed by CIESIN in collaboration with Connectivity Lab at Facebook and Digital Globe.[99] This is a raster dataset of Kenya's settlements derived from a land use/cover classification of Kenya using Landsat satellite imagery where each pixel represents a building or structure on the earth's surface.

Demonstration of the SW Maps application

Converted to point data, the settlements dataset provides an exhaustive household listing in each village from which random selection of the target households will be done. Additional households (10% of the target sample) were selected as replacements for households that would be unwilling or unavailable for the household interviews.

The selected households were loaded onto SW Maps, which is an android-based geospatial application that allows for interaction with geospatial layers and real-time navigation using GPS and GLONASS. Each household was labelled with a unique number for ease of identification by the enumerators. The figure below shows a snapshot of the SW Maps interface during data collection. The red triangles signified the main target households while the yellow dots indicate replacements for when the main house is unavailable or could not be interviewed. The blue dot indicates the current location of the enumerator.

Selection of enumerators and supervisors

EED Advisory has a database of 253 enumerators nationally spread across all the 47 counties and who understand the socio-cultural norms of these counties and speak the local languages as well as English and Kiswahili. These enumerators have worked directly with EED-A on previous engagements and are therefore familiar with the use of CAPI and SW Maps. If some of these enumerators were not available, the following criteria were applied to select replacements.

Enumerators had to:

- Be conversant with (preferably resident in) the area in which they were conducting the interviews. Understand and speak the local language in the area they would be conducting the interviews.
- Be familiar with the political and administrative boundaries of the survey areas.
- Be fully available for the entire duration for which the interviews would be carried out.
- Provide a valid original Kenyan National Identification Card.
- Provide proof of graduation from a University recognized in Kenya. Diploma holders with substantial data collection experience were considered especially in the underserved counties.
- Provide their current telephone contact.
- Attend an enumerator training session before undertaking any survey interviews.
- Demonstrate ability to collect data using CAPI.

The enumerators were trained and tested. The training program was over two days where enumerators were trained on the objectives of the study, questionnaires including the definition of terms, interviewing etiquette, and best practices in asking questions. They were also trained on the survey tools installed on the tablets including Survey CTO and SW Maps. Mock Interviews and a pre-test exercise were integrated into the training program. Each enumerator was assigned a unique identification number and a supervisor.

The enumerators were under the leadership of regional supervisors who reviewed submitted data and performed random checks to certify that the information collected was accurate.

The regional supervisors were drawn from EED-A staff and were responsible for training and coordinating the survey teams, checking the work done by enumerators, and leading introduction meetings with the relevant authorities before embarking on the data collection. They were the first contact point in case of any technical and logistical challenges faced by the data collection enumerators. A total of 16 supervisors participated in pre-survey training before being deployed into the field. The supervisors provided the enumerators with reports of any errors observed in verified submitted data to ensure errors were not carried forward.

Pre-testing survey tools and supervisor training

A two-step pre-testing exercise was carried out. The first pre-test was conducted in Busia and Kajiado on 17/12/2020 to assess the duration of the interview, respondents' comprehension of the questions, logical flow of the questionnaire and structure of each question, appropriateness of the answer options. The exercise was used to refine the questionnaire by detecting problems with the questionnaire design, highlighting sensitive questions, identifying redundant, and ambiguous questions. The second pre-test exercise was carried out on a need-only basis in the different regions over the four-week data collection period. The pre-test exercise was used to train the enumerators on the use of SW Maps and Survey CTO.

Computer-Aided Personal Interview (CAPI)

SurveyCTO

The survey was implemented through Computer-Assisted Personal Interviewing (CAPI) tools on the Survey CTO platform. The questionnaire provided by the VeraSol team was revised and then coded. The SurveyCTO provided both data verification and validation checks; recording GPS, audios, start-time, end-time, and dates; taking pictures via camera and signatures, and uploading various file formats. It also provides a central server where all the data is submitted for export to STATA for analysis or downloaded as a CSV or XLSX format.

SurveyCTO was uploaded on all the tablets before distribution to the enumerators and supervisors. The set-up software is cross-compatible on Windows, Mac, and Linux platforms. Detailed training on using SurveyCTO for this survey was provided to the supervisors and enumerators during the pre-testing period. As expected, certain sites did not have access to power to charge the tablets therefore the enumerators being dispatched to these areas were given portable power sources to ensure their tablets were always charged during the interviews.

SW MAPS

The randomly selected enumeration areas, county sub-locations, and randomly selected households per county were overlaid on SW Maps, a GIS android application that can collect, present, and share geographic information. The App-enabled enumerators navigate to the enumeration areas in real-time and provide live maps of the enumeration area, sub-locations, and the randomly selected households. Information (electrification status, rural-urban status, and administrative information) on each enumeration area was also visible on the App. SW maps can also record GPS tracks and measure distances.

GIS Database

The survey questionnaires were set up to collect the GPS coordinates of all the interviews carried out. To do this, each tablet's inbuilt location service was switched on to automatically record the GPS coordinates onto the SurveyCTO questionnaire. The tablet's location services and SW Maps facilitated the movement of enumerators and supervisors in the field as they could locate and plan for transport based on distances and accessibility. All the surveys with the correct spatial information (County name and Cluster Unique Id/EA Id) can be presented in shapefile (.shp) and Google Earth (. kml/.kmz) format.

Categorization of QV and non-QV Products

The Kenya Consumer OGS survey tackled the question of brand and brand model through four main questions. Enumerators were trained on differentiating between a brand and a brand model and taking images of the serial number for each product they encountered. During the data cleaning process, the brand names and brand models indicated and images taken were counter-checked against the VeraSol product certification list compiled from 2010 to 2021.

The QV product certificate is issued for two years after which it has to be renewed. Therefore, to ensure the products are certified within the period of the valid license, the brand model was characterised based on the year of purchase. However, for cases where the year of purchase was not indicated the following steps were used to simplify the identification of QV products:

i. If the product was ever QV and was purchased on or after the date of the first qualification, mark it as QV.

ii. If the product was ever QV and the purchase date is unknown, mark it as QV and flag it for further research later. (Further research may or may not be warranted, depending on what we find.)

iii. If the product was ever QV and it was de-certified and the product was purchased on or after the date its certificate was revoked, mark it as non-QV.

A total of 4,195 interviews were carried out; of these, 1,414 respondents reported owning a solar product. 1205 products were identified by their brand name. The breakdown of products identified using multiple steps is indicated below:

i. Brand models identified through enumerator's observations and images taken – 761 products

ii. Brand models correctly identified but no purchase date indicated – 45

iii. Products that had the correct brand identified, categorised as a solar lighting, system, solar home system and the year of purchase – 30

iv. For the remaining products, 578 products – 453 calls were made to confirm some unknown brand model types and also identify those whose status was unknown. 167 products were identified over the calls using descriptions of the brand and brand model characteristics. An example of the criteria used for M-KOPA is shown below. From the entire dataset of 1414 solar products, about 411 were not identified by brand nor brand model.

About 650 data points of the total 1414 were also captured with an image of the solar energy kit. They formed the basis of the QV and non-QV assessments, as these products could be definitively verified by the EED and VeraSol teams. Our review began by viewing the photo for each of the products, and reviewing the recorded information about the product model, reported date of purchase, and QV/non-QV status. These products were categorised as 471 QV products, 117 non-QV products and 22 products could not be classified therefore termed as 'unknown'. For the rest of the analysis that did not require a comparison on a verification basis, the entire sample size of 1414 was used during analysis.

M-KOPA

1. Can you please confirm the solar product brand used is M-KOPA?

2. Are you near the battery pack? (The black device indicating charge)

3. Please check the bottom right corner for the name and number. (*The model numbers are indicated on the bottom right corner of the battery pack*)

4. If the respondent is not home or cannot identify the model number through steps 1 – 3 please use the following questions.

M-KOPA				
LIGHTING SYSTEMS				
	QUESTION	RESPONSE	BRAND	IMAGE OF PRODUCTS
1.	Does it have 2, 3 or 4 lights? Was it purchased with a TV?	If purchased with a TV skip to the home systems section		
a)	(2/3/ lights) Does it have a radio?	No	M-KOPA 3	
		Yes	M-KOPA 4	
b)	(4 lights) Is it 4 bulbs?	Yes	M-KOPA 5	
c)	Is it 3 bulbs and 1 fluorescent tube?	Yes	M-KOPA 6	
HOME SYSTEMS				
1.	When was it purchased?			
2.	Please check the bottom right corner of the battery pack. What is the number?	M-KOPA 400		
		M-KOPA 500		
		M-KOPA 600		
	Is one of the bulbs a fluorescent bulb?	M-KOPA 600		

Image credit: SunnyMoney

Endnotes

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16 0.04

17 0.01

18 $P < 0.046$

19 $P < 0.573$

20 $P < 0.2031$

21 0.01

22 0.03

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60 $P < 0.043$

61 $P < 0.019$

62 $P < 0.554$

63 $P < 0.392$

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66 $P < 0.046$
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77 $P < 0.05$
78 $P < 0.009$
79 $P < 0.028$
80 $P < 0.368$
81 $P < 0.097$
82 $P < 0.921$
83 $P < 0.003$
84 $P < 0.011$
85 $P < 0.011$
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