

Shell Foundation | 

Improving the Quality of Life of Kenyan Households with Off-Grid Solar Home Systems



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Greenlight Planet



Greenlight Planet designs, distributes and finances Sun King solar home energy solutions to households and businesses who lack reliable access to the grid. Since its founding in 2008, the company has become a leading global provider of solar home energy products

to over 55 million rural consumers in collaboration with 300 partners across the world. Throughout the last decade, the company has grown steadily, building expertise in developing high-quality solar-powered home energy solutions, last mile distribution, and consumer financing through its unique 'pay-as-you-go' (PAYG) technology. More than 12 million Sun King products are currently installed in more than 60 countries in Asia, Sub-Saharan Africa, and Central America.

Greenlight Planet continuously strives to meet the evolving needs of the off-grid market. Its wide range of trusted Sun King solar lamps and home energy systems deliver high performance and long shelf life. Greenlight Planet's innovative pay-as-you-go technology, EasyBuy allows customers to pay for Sun King products in small installments over time making solar energy affordable even for consumers with limited savings. The Sun King EasyBuy range was designed to address the challenges of consumer affordability: leveraging its unique PAYGO technology, Greenlight can afford end consumers the option to pay for their solar energy solutions through a longer-term installment plan. Through this offering, consumers receive an 'unlock token' with each regular, incremental payment enabling their system to work for a period of time. Once they complete the series of payments, the final token perpetually unlocks the system, freeing up previous energy spend as household savings.

www.greenlightplanet.com

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
BoP	Bottom of the (economic human) pyramid
CO2	Carbon dioxide
GCP	Gross county product
GDP	Gross domestic product
GOGLA	Global association for the off-grid solar energy industry
PAYGo	Pay-as-you-go
PV	Photovoltaic
SHS	Solar home system
UN	United Nations
USD	United States Dollar
Wp	Watt-peak

KEY DEFINITIONS

Access to electricity	Electricity access refers to the percentage of people in a given area that have relatively simple, stable access to electricity ¹ . Traditionally, it has been measured on the basis of household connections to the national electric grid of their country. Recently, however, the definition is being expanded to account for different levels of electricity access by a range of technologies. As not all countries and areas have equal access to electricity, it can serve as a good proxy for other indicators such as wealth and opportunity in a country. ²
County (Kenya)	The counties are the geographical units of Kenya after the reform of the 2010 constitution. As stated in Art. 6 of the Kenyan constitution, “the territory of Kenya is divided into (the) counties”. ³ The governments at the national and county levels are distinct and inter-dependent. According to Art. 98, each county constitutes a single member constituency in the Senate. ⁴ As of 2013, following the general elections, 47 counties were constituted, which merged the until then 280 legally constituted Districts of Kenya. Before 2013, these districts were grouped into provinces (see description below). ⁵
Energy ladder	Anecdotal evidence in the world of off-grid lighting solutions in developing countries has pointed to a so-called “energy ladder”, in which some first-time buyers of small solar-powered products such as solar lanterns eventually buy into a larger home system. ⁶
Financial inclusion	Financial inclusion means that individuals and businesses have access to useful and affordable financial products and services that meet their needs, including transactions, payments, savings, credit and insurance. These are to be delivered in a responsible and sustainable way. ⁷
GDP	The GDP, or gross domestic product, measures (1) the monetary value of final goods and services bought by the final users produced in a country in a given period of time, (2) the expenditures by final users, and (3) all income from productive activities within the borders of a country. ⁸
Household	Household members are individuals who sleep under the same roof and eat the same food. It can include domestics if their situation matches the definition.
Off-grid population	Households or people that lack access to an electricity connection to the national grid.

Pay-as-you-go (PAYGo)	Digital financing technology that allows end-users to digitally pay for solar energy in regular instalments (e.g. daily, weekly or monthly). In the context of this report, PAYGo removes the initial barrier to solar energy access by allowing consumers to make a series of modest payments to purchase a week’s worth of solar energy rather than paying upfront for the entire solar lighting system. Pay-as-you-go in the context of this study refers to Greenlight Planet’s Sun King EasyBuy platform. ⁹
Province (Kenya)	Prior to the 2010 Constitution, Kenya was subdivided into eight provinces and 280 districts. The eight provinces were the following: Central, Coast, Eastern, Nairobi, North Eastern, Nyanza, Rift Valley and Western. ¹⁰
Solar Home Systems	Solar Home Systems (or SHS) are stand-alone photovoltaic systems that offer a cost-effective mode of supplying amenity power for lighting and appliances to remote households. In this research “Solar Home System” or “SHS” is used to refer to multi-light systems (3-10.999 Wp) and solar home systems (>11 Wp) ¹¹ .

¹ International Energy Agency. (2017). *Modern Energy for All*.

² World Bank – ESMAP. (2015). *Se4All Technical Assistance Program*.

³ Constitution of Kenya. (2010). *Article 6, Devolution and access to Services*.

⁴ Constitution of Kenya. (2010). *Article 98, (1) (a) Membership of the Senate*.

⁵ Institute of Economic Affairs. (2014). *First county integrated development planning*.

⁶ GOGLA. (2016). *Team of Researchers Launch Yearlong Study of Uganda’s Energy Ladder*.

⁷ World Bank. (2018). *Overview of financial inclusion*.

⁸ International Monetary Fund. (2018). *Gross Domestic Product: An Economy’s All*.

⁹ See Greenlight Planet’s webpage: <https://www.greenlightplanet.com/easybuy/>

¹⁰ OECD. (2016). *Kenya Unitary Country*.

¹¹ GOGLA. (2019). *Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data*.

EXECUTIVE SUMMARY

Today, 840 million people worldwide still lack access to energy, and most of them live in Sub-Saharan Africa (SSA).¹² Off-grid solar products seek to provide an answer to this: in 2019, 280 million people had enjoyed an improved electricity access thanks to an off-grid solar source.¹³ Overall, off-grid solar is playing a key role in helping to achieve SDG 7, contributing to an affordable and clean energy access for all. What is more, energy is only an “intermediate” commodity. It is valued not so much for its own sake as for the services it enables, and these services contribute to a big extent to the achievement of many other SDGs.¹⁴

As part of this research, we interviewed 1,001 individuals randomly selected from Greenlight Planet’s customer base of solar home system (SHS) customers. The sample is representative of current Greenlight Planet Solar Home 60 and 120 customers in Kenya and not automatically of a larger population group. However, it seems likely that the nature of benefits and costs would be similar for new customers across Kenya and potentially other East African countries with similar characteristics in terms of rural household energy use and energy mix.

Almost half of customers interviewed live with less than \$3.20 per day, the World Bank poverty line for lower middle-income countries. The majority of households rely on agriculture for their livelihood. They use the SHS at home for lighting and phone charging.

The study shows that the impacts of solar home systems on a households’ life are very diverse. On average, solar home systems double the hours of light available to a household, while also helping to reduce more than 75% of total kerosene use. They enable children to spend almost two extra hours per day doing homework. Owners feel healthier and safer thanks to the system.

Households are also increasingly connected to information, as they double the time spent listening to local news. Furthermore, these impacts are felt most strongly among poorer households and households where women are the main users of the system.

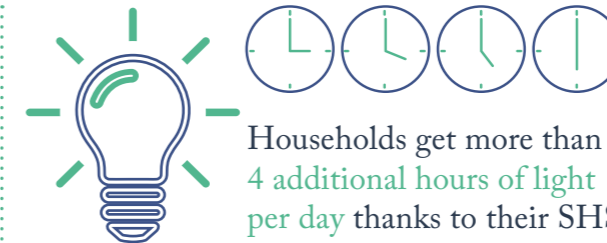
The overwhelming majority of households are satisfied with their decision to purchase their solar home system hinting to an overall net socio-economic impact. To benefit from this impact, households may need to make adjustments. For example, a third of households report having at least once asked for money or a loan to pay for their SHS and half of households report adjusting their expenses (i.e. spending less on other areas of expenditure).

In conclusion, affordable solar home systems are helping reach low-income households and improve their lives in many ways. In this research we offer evidence that solar home systems, by providing access to energy (SDG 7), are contributing to good health and well-being (SDG 3), quality education (SDG 4), gender equality (SDG 5), decent work and economic growth (SDG 8), reduced inequalities (SDG 10), climate action (SDG 13) and peace, justice and strong institutions (SDG 16).

KEY FINDINGS



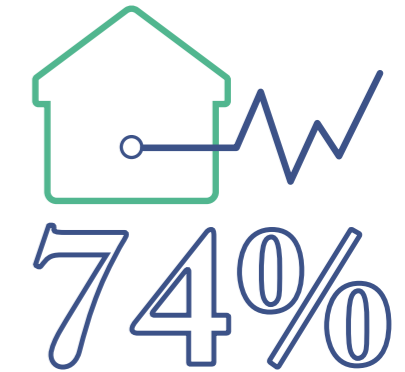
of households interviewed live **BELOW** the \$3.20 per day poverty line



Households get more than **4 additional hours of light per day** thanks to their SHS



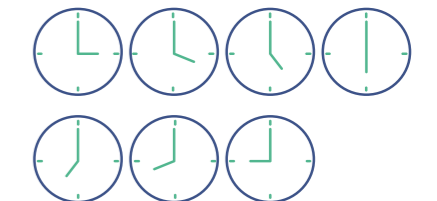
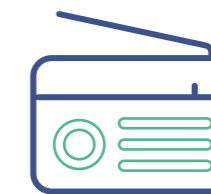
As a result, households eliminate **2.5 hours of kerosene light per day**, in total reducing **75% of kerosene use**



of households feel **healthier** thanks to the SHS, as they are **less exposed** to fumes from kerosene



SHS allow children to spend almost **2 extra hours per day DOING HOMEWORK**, thus improving the grades of **88% of children**



Households spend **7 hours** more listening to the radio per week, doubling (x2) the time **listening to local news**

87% of households feel **SAFER**

thanks to the adoption of the SHS, primarily by **keeping robbers away** from the house



A MAJORITY OF HOUSEHOLDS

have made adjustments to be able to continuously pay for their SHS. **58%** of households have experienced decreasing purchasing of food, **48%** on clothes and **41%** on education. **36%** of households had asked for additional formal or informal loans to pay for their SHS



Moreover, **poorer households and households where women are the main users** of the system are more likely to report high levels of **POSITIVE SOCIO-ECONOMIC IMPACT**

NEVERTHELESS,



only a very small share of households (**8%**) have regretted the decision to buy a SHS, thus hinting to a positive net socio-economic benefit

¹² The World Bank, the International Energy Agency, the International Renewable Energy Agency, the United Nations Statistics Division and the World Health Organization. (2019). *Tracking SDG 7: the Energy Progress Report*. Washington, The World Bank.

¹³ GOGLA. (2019). *Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data*.

¹⁴ United Nations. (2019). Policy Brief #8. Accelerating SDG 7 Achievement. Policy Briefs in Support of the First SDG 7 Review at the UN High-Level Political Forum,



INTRODUCTION

This report focuses on the net socio-economic impact of the off-grid solar industry, an industry that has benefitted more than 280 million people to date. This industry has been widely covered by research efforts from international organizations and academics alike. However, this study confirms and complements existing work on the socio-economic impact of solar home systems by conducting 1,001 interviews with solar home systems owners. The results include new impact measurements and explore how the impact is reaching Kenyan low-income households.

CONTEXT

According to the last Global Sustainable Development Report, we are not on track to achieving most of the 169 targets that comprise the Sustainable Development Goals (SDGs).¹⁵ Ten years remain to achieve the 2030 Agenda of SDGs, but most countries are struggling to meet a set of basic human needs at a globally sustainable level of resource use.

In the four years since the SDGs were created, developing nations have put a lot of emphasis on access to energy. As of 2017, 840 million people worldwide lacked access.¹⁶ Lack of access is even more common in rural areas where electrification efforts are particularly challenging. For traditional utilities, the cost necessary to reach remote and often very scarce and dispersed populations is high.

Off-grid solutions, including solar home systems (SHS), therefore appear necessary to reach the United Nation's 7th Sustainable Development Goal of ensuring access to affordable, reliable, sustainable and modern energy for all by 2030.

“Cheaper renewable energy technologies, the rising role of electricity and digital applications are critical vectors for change in providing energy services, while fossil fuels can be replaced [...] and efforts can be scaled-up for energy efficiency and the promotion of renewables”

– Global Sustainable Development Report, United Nations (2019).

The off-grid solar industry is growing and adapting to increased and more diverse demands from customers. More customers, especially in East Africa, choose pay-as-you-go (PAYGo) products to make use of the benefits of off-grid solar without paying for the full amount upfront, with PAYGo annual sales surpassing one million lighting units for the first time in 2018.¹⁷ Off-grid solar's impact has reached a significant scale as the cumulative number of people who have benefitted from improved electricity access through off-grid solutions has reached 280 million.¹⁸

However, the importance of off-grid solar goes beyond the sales numbers. Dozens of social, environmental and economic indicators must be considered, ranging from issues such as reducing emissions to education and financial

inclusion. According to the United Nations, affordable and clean energy is an “intermediate commodity”, that is valued for the services it enables. SDG 7 is thus primarily useful in that it helps achieve other SDGs. In this report we will see that progress in reaching SDG 7 through SHS also impacts on good health and well-being (SDG 3), quality education (SDG 4), gender equality (SDG 5), decent work and economic growth (SDG 8), reduced inequalities (SDG 10), climate action (SDG 13) and peace, justice and strong institutions (SDG 16).¹⁹



Figure 1: Overview of the 17 Sustainable Development Goals, United Nations

The need is spread among different geographies, but predominantly concentrated in Sub-Saharan Africa (SSA). While worldwide only 9% of the population lives without access to energy, this is true of more than 50% of the population of Sub-Saharan Africa.²⁰ Within SSA, Kenya is a flagship country for off-grid solar energy. The Kenyan market has been a pioneer in terms of adoption of solar home systems and the PAYGo business model, in part thanks to widespread usage of mobile money. Today the market is the most mature on the continent with most of the largest vertically integrated PAYGo players present and fierce competition for customers. At the same time, awareness and understanding of off-grid products and PAYGo financing is higher in Kenya than in most other off-grid solar markets. This leads customers to know brands, value quality products and understand pricing allowing them to compare offers from different companies. Yet the market is far from saturated with many in Kenya still without access to electricity or reliable electricity on the one hand and customer needs evolving towards bigger systems and more appliances on the other hand.²¹

The Government of Kenya and the World Bank believe off-grid solar can play a key role in reaching the unserved as demonstrated by the Kenya Off-Grid Access Project (KOSAP) which will provide support to off-grid companies in reaching 14 underserved counties by providing Result Based Financing to off-set the cost of expanding into these sparsely populated counties.²²

In a context of strong growth for PAYGo solar home system sales and public investment in the sector, this report aims at assessing the net socio-economic impact of these products in Kenya, to provide strong insights to a wide variety of stakeholders. First, this report aims at helping investors get a better understanding of the sector that will create incentives for additional and stronger private sector participation. Second, we want to give development agents tools to assess the non-economic impact of sustainable solutions in the industry, obtain lessons learned, and target their actions where they deliver the most impact. Third, this piece of research provides elements of context for policymakers when developing a regulatory framework that can make this nascent industry thrive.

¹⁵ United Nations. (2019). *Global Sustainable Development Report*.

¹⁶ The World Bank, the International Energy Agency, the International Renewable Energy Agency, the United Nations Statistics Division and the World Health Organization. (2019). *Tracking SDG 7: the Energy Progress Report*. Washington, The World Bank. GOGLA. (2018). *Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data*.

¹⁷ GOGLA. (2018). *Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data*.

¹⁸ GOGLA. (2019). *Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data*.

¹⁹ United Nations. (2019). Policy Brief #8. Accelerating SDG 7 Achievement. Policy Briefs in Support of the First SDG 7 Review at the UN High-Level Political Forum,

²⁰ Tracking SDG 7. (2019). *The Energy Progress Report*, pp. 4-5.

²¹ Assessment based on Altai Consulting interviews with key stakeholders and experts in Nairobi

²² For more information, see <https://kosap-fm.org/>

LITERATURE REVIEW

The relevance of this subject has driven multiple sources of empirical research, which have caught the attention of the public in recent years. While several studies have focused on the impact of off-grid solar, this piece of research aims at complementing the existing literature with new impact measures and a more in-depth understanding of the impact data in the specific context of Kenya.

The existing literature has focused on multiple aspects and impact measurements in the industry.

First, recent research includes several publications led by GOGLA²³, the voice of the off-grid energy industry. These reports, grouped under the Powering Opportunity series, have collected data showcasing the socio-economic impact SHS can have on households. They are multi-country analyses and consolidate results for SHS of all sizes.²⁴ Among their results, 28% of users in East Africa²⁵ and 14% in West Africa²⁶ reported being able to generate more income thanks to SHS. Additionally, 89% of the users in East Africa and 86% in West Africa report their health improved. Moreover, 86% of customers in East Africa and 91% in West Africa say children have more time to do their homework. Finally, 91% of customers in East Africa and 98% in West Africa feel safer thanks to off-grid solar.

Second, the data obtained for these reports, along with other sources, have been used by GOGLA to design impact metrics which provide the basis for the impact figures published in the Semi-Annual Sales and Impact Data published by GOGLA and Lighting Global. GOGLA's impact metrics show that over 100 million people currently live with improved access to energy, that 66.6 million metric tonnes of CO2 emissions have been avoided and that 63 billion hours of additional light have been used since 2010 through off-grid solar adoption.²⁷

Third, other organisations that published impact reports include institutes and impact investment funds. Acumen's 2017 Energy Impact Report²⁸ highlights the impact of the 20 companies in their portfolio in Africa and South Asia. They have focused mostly on economic impact and on punctual social indicators, including safety and kerosene reduction. They account for 81 million people benefiting from the adoption of a SHS. 20% of them are using their energy products for income-generation and 49% of them feel safer after the adoption of the SHS.

Fourth, the global partnership under the Consultative Group to Assist the Poor (CGAP) has released several studies²⁹ in recent years that focus on the impact and benefits of PAYGo. Their key area of research is the dynamics of the PAYGo business model and the impact it has on budgets and households willing to purchase a solar product.

Finally, several research institutions have published academic reports on the subject. These reports have covered a variety of subjects in this industry (e.g. the impact of solar lanterns³⁰, the relevance of waste management with solar products³¹, etc.).

OBJECTIVES

The Shell Foundation has been working to enhance access to energy since 2000. In particular since 2003, this effort has been carried out by supporting market-based solutions and social entrepreneurs to reach low-income households. Learning from the challenges and failures experienced by these entrepreneurs, the Shell Foundation developed an approach³² to help catalyse the systemic change required for these solutions to reach scale by helping to develop market-enablers. Market-enablers include supply chain service providers, financial intermediaries and catalytic institutions.

As part of this effort to help enterprises contributing to SDG 7 to reach scale, Shell Foundation has provided grant funding and support to several leading providers of off-grid solar home systems (SHS) sold through the Pay-As-You Go (PAYGo) model: BBOX, d.light, Greenlight Planet, M-KOPA, etc. These companies have been hailed as champions of energy access for their ability to make energy access solutions affordable to low-income households.

This research was made possible through the participation of Greenlight Planet. For over a decade, the company has marketed affordable lanterns and solar home systems. The company sells these products both on a cash basis as well as through their 'Sun King EasyBuy' pay-as-you-go payment plans; the latter allows us to explore the impact of PAYGo systems on reaching low-income households. Greenlight Planet has provided access to their customers and has actively supported the project.

Beyond the existing literature, further research is needed to understand who these products are reaching and what impact they are having on different user households. This study will expand the literature in the field by enriching the understanding of impact in a way that could be potentially replicated in future impact research in the off-grid sector and in other contexts. This research provides three main innovative points compared to the existing literature:

- 1 This study aims at reducing the gap in the literature on impact of small and affordable solar home systems
- 2 This study aims at providing granular evidence of impact disaggregated by the income level of households

- 3 This research provides new impact measures providing more in-depth information and complementing existing impact data

First, as mentioned above, this research is entirely focused on the impact of smaller solar home systems providing tier one access to electricity³³. This approach is interesting because small and affordable systems are most likely to reach low-income households, but also because SHS ranging from 3 to 21 Wp have represented the majority of SHS sales over the last two years.³⁴

Second, all impact measures have been segmented based on household income-levels which have been assessed based on the Poverty Probability Index (PPI®).³⁵ This provides a new and crucial dimension to the definition of impact which has not been exploited in the literature.

Third, the research provides new insights into the impact of solar home systems such as better understanding their effect on education, safety, health, financial inclusion and access to information. Furthermore, this research includes adjustments made by customers while paying for their SHS, a new angle to expand the understanding of the net impact of solar home systems.

Finally, this study is solely focused on Kenya. This allows to deep dive into the market's context as well as income levels and geographical nuances of the country. All in all, this piece of research would like to expand the availability of impact data and test a methodology that can be replicated in other countries while being tailored to each context.

²³ Shell Foundation provides funding to GOGLA

²⁴ In this research, the term solar home system will encompass systems ranging from 3Wp to 200Wp. Please note that 3-10Wp products are generally referred to as 'multi light and phone charging kits' and 10-200Wp products as solar home systems

²⁵ GOGLA. (2019). *Powering Opportunity in East Africa: Proving Off-Grid Solar is a Power Tool for Change*.

²⁶ GOGLA. (2019). *Powering Opportunity in West Africa: Improving Lives, Powering Livelihoods with Off-Grid Solar*.

²⁷ GOGLA. (2019). *Standardized Impact Metrics for the Off-Grid Solar Energy Sector*.

²⁸ Acumen. (2017). *Energy Impact Report*.

²⁹ CGAP. (2017, 2018). *Escaping Darkness, Strange Beasts and Taming the Strange Beasts*.

³⁰ Harrison, Muwowo, Stojanovski, Thurber and Wolak. (2018). *Assessing Opportunities for Solar Lanterns to Improve Educational Outcomes in Rural Off-Grid Regions: Challenges and Lessons from a Randomized Controlled Trial*. Stanford University – Center on Global Poverty and Development.

³¹ Cross and Murray. (2018). *The afterlives of solar power: Waste and repair off the grid in Kenya*, *Energy Research & Social Science*, Volume 44, Pages 100-109

³² For more information, Shell Foundation. (2018). *Accelerating Access to Energy: Lessons learned from efforts to build inclusive energy markets in developing countries*.

³³ SE4ALL (2016), *Beyond Connections: Energy Access Redefined*

³⁴ GOGLA. (2019). *Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data*, January - June 2019, Public Report. GOGLA. (2018). *Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data*, July - December 2018, Public Report. GOGLA. (2018). *Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data*, January - June 2018, Public Report.

³⁵ The Poverty Probability Index (PPI®) is a poverty measurement tool originally developed for the Grameen Foundation based on simple 10-point poverty scorecards. The PPI® Alliance is now led by the IPA. <https://www.povertyindex.org/>

METHODOLOGY

Research focus:

This research effort is targeted, as it focuses on one solar home system provider, two products and one country: Greenlight Planet's Sun King Home 60 (6Wp) and Home 120 Plus (12Wp) units³⁶ in Kenya.



Figure 2: Display of both the Sun King Home 60 and Home 120 Plus SHS, from Greenlight Planet

These systems represent the vast majority of Greenlight Planet's portfolio of SHS in Kenya. 6Wp systems typically include three lamps (with 100 lumens per lamp) controlled by wall-mounted switches, a solar panel, a charging kit with a USB cable, phone adapters and a radio. 12W Plus systems are very similar to 6W systems, the difference being that

they include four brighter lamps (200 lumens per lamp), one additional lamp with a motion sensor, a solar panel and battery with twice the capacity. All systems have a standard 2-year warranty. The systems are sold on a pay-as-you-go basis with an average repayment period of nine months.

Interviewees for this research were selected among customers having purchased their product between 2016 and 2019, with ~10% that have finished paying for their product.

	Home 60 (inc. radio)	Home 120 Plus (inc. radio)
Capacity	6Wp	12Wp
Quantity of visible light	Three lamps of 100 lumens each	Four lamps of 200 lumens each and one lamp with motion sensor of 100 lumens
Total cost (KSh)	13,785	17,980
Down payment (KSh)	1,500	1,600
Expected repayment period	9 months	9 months

³⁶ Greenlight Planet also provides a 40Wp Sun King system including a TV. This product has been part of the company's product portfolio for a shorter amount of time and has therefore not been included in this research. See <https://www.greenlightplanet.com/>

The type of products chosen has implications for the expectations of the research, as these systems are sold mostly for home use and provide solutions for basic lighting needs and phone charging. Because it is a study that is fully focused on two system sizes, one of the objectives of this research is to leverage this situation by exploring how much a minor change in size (from 6W to 12W) can impact the socio-economic situation of households.

No other constraints, aside from solar home system size, brand, duration of ownership and geographic location, have been applied in this research. Households come from a range of different counties within Kenya, work in various industries and belong to different income levels. The sample analysed here is a sample of 1,001 customers from Greenlight Planet's Kenyan portfolio of SHS customers. The sample was randomly selected among the target population in Greenlight Planet's customer base in an attempt to provide insights representative of the company's solar home system customers.

Aligned with previous literature, this research gathers data by household instead of on an individual basis. As households share the solar home system, data by household is more representative than on an individual basis to assess the socio-economic impact of the systems.

Data collection and analysis:

The data collection consists of a sample of 1,001 customers of Greenlight Planet that owned one of these two SHS in Kenya. The interviews were carried out by Sagaci Research under supervision of Altai Consulting. Altai Consulting provided specific training and data quality reviews to ensure that the final data set was consistent and robust. Data was then centralised and analysed by Altai Consulting.

With such a sample size, the margin of error is typically of +/- 3% at 95% confidence-level for the target population: Greenlight Planet Solar Home 60 and Solar Home 120 customers in Kenya, in 2019.

Throughout this report we have first analysed each of the customer and impact categories as a stand-alone, and then performed several cross-analyses to give additional context to the findings provided. Cross-analyses could be by SHS size, province, income level, gender of the main user, etc. To avoid repetition, this report will only showcase cross analyses that show statistically significant results.

Income distribution:

The income distribution of the sample of customers was calculated using the Poverty Probability Index (PPI®). The PPI® is a statistical poverty measurement tool comprising of ten questions or indicators about a household's characteristics and asset ownership. These ten questions have been updated for the Kenyan population in 2015, so that the statistical results reflect the reality on the ground. Answers are scored to compute the likelihood that the household is living below the poverty line. For some aspects of the research the PPI® methodology has been adjusted to be able to leverage these results in the context of impact measurement (See Annex).

Definition and wealth at county and province level:

In this research we will include information at a sub-national level. This particular analysis will allow us to observe trends based on the geographic location of the household. In particular, outputs at a sub-national level that are correlated to the average wealth of the region can help us draw interesting insights. In this research we will focus on the subdivision by the former provinces, not counties. This subdivision is the only one possible to draw statistically significant insights, as a split of 47 different counties will have a high margin of error. The economic level of each province has been derived from the gross county product in 2018/19³⁷ divided by the population in 2018³⁸ (See table)³⁹.

Province	Per Capita Gross Province Product (KSh)
Nairobi	339,390
Central	203,555
Rift Valley	155,618
Coast	151,279
Eastern	129,942
Nyanza	122,349
Western	101,922
North Eastern	44,840

³⁷ Kenyan Bureau of Statistics. (2019). *Gross County Product*.

³⁸ Kenyan Bureau of Statistics. (2019). *Kenyan Population and Housing Census*. The population information disclosed in the Gross County Product report is not aligned with other sources, and therefore we stick to the census for population data.

³⁹ Data available in Annex



CUSTOMER'S PROFILE

The typical user of a solar home system in this research lives in a household of six members, three of them women, in the Nyanza or Western province, two of the three poorest provinces of Kenya in terms of GDP per capita, and works on agriculture earning less than USD 3.20 per day. His or her family owns a 6Wp system, which is the first solar product they acquired. They use it at home to have more light at night and to charge their phones.

SOCIO-DEMOGRAPHICS

Household size and composition

The average household size is approximately six members. The household size is on average significantly larger than the Kenyan average, which is four members per household⁴⁰. On average, 49% of household members in this research are women which is in line with the country average, at 50%.⁴¹

There is no strong correlation between household size and system size: Households that purchased the 6Wp product have 5.9 members on average, compared to households that purchased the 12Wp product, which have an average size of 6.3 members. Furthermore, this difference is mostly driven by the income level of the household.⁴² There are no relevant differences in the average household size in the different provinces. The provinces with the highest number of members per household are the Rift Valley and Coastal provinces, both with 6.2 members.⁴³

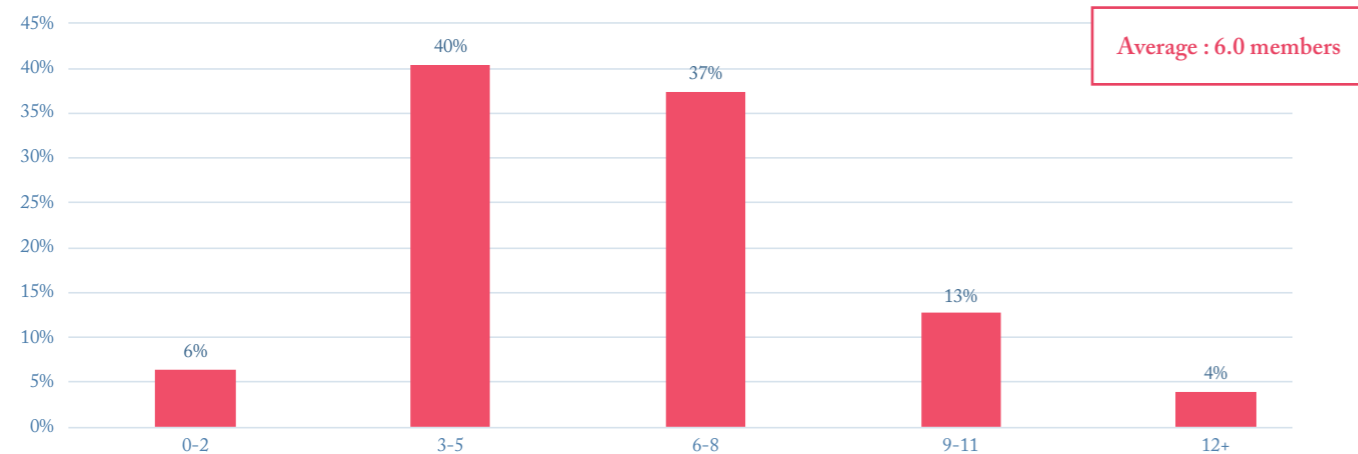


Figure 3: Household size [share of respondents]; N=1001

Gender of the interviewee, purchaser, payer and user

57% of interviewees were male. These results are coherent with the share of respondents that answered that a male was responsible for deciding to purchase the system (54%) and the share of respondents that answered that a male was responsible for making the payments to the solar home system provider (63%). When it comes to using the system, the majority of households reported that both male and female were the main users of the system (70%). In the remaining households, the proportion of female main users is more than twice the proportion of male main users (22% vs. 8%).

Province

More than half of the households live in the Nyanza and Western provinces, with a 28% and 26% share of the customer sample respectively. However, the share of the Kenyan population living in those two provinces (13% and 11%) is significantly lower. According to the Kenyan Bureau of Statistics, these two provinces are also two of the three poorest provinces by income per capita in Kenya.⁴⁴ The distribution of the sample in Rift Valley, Eastern and Coastal is proportionate to the distribution of the Kenyan population in these provinces. The provinces of Nairobi and Central, the two richest provinces in the country, have very little representation in the customer sample (with only 3% of the sample overall). Finally, the North Eastern province, the province with the lowest income per capita, has no representation in the sample. Limited penetration of off-grid solar in this region is a well-known issue. This situation is likely to evolve as the Kenyan Ministry of Energy and the World Bank have already begun addressing this problem by launching the KOSAP project, targeting expressly access

⁴⁰ Kenya Bureau of Statistics. (2016). *Kenya Integrated Household Budget Survey*.

⁴¹ World Bank. (2018). *World Bank Data Bank*.

⁴² Based on an analysis by both income and system size.

⁴³ The households in the Nairobi and Central provinces have the fewest number of members but the sample size for these provinces is too small to produce robust data.

⁴⁴ See Annex for more details.

to energy in the “North East and Northern [regions of] Kenya”.⁴⁵ The project’s stand-alone solar component aims at electrifying 250,000 households through SHS by helping off-grid companies expand into the region through result-based financing.

“The program is 100% private sector led and market-based. Companies determine the business and distribution model and we select the most competitive bids.”

Maarten Kleijn – Senior Officer Off-Grid – SNV (former)

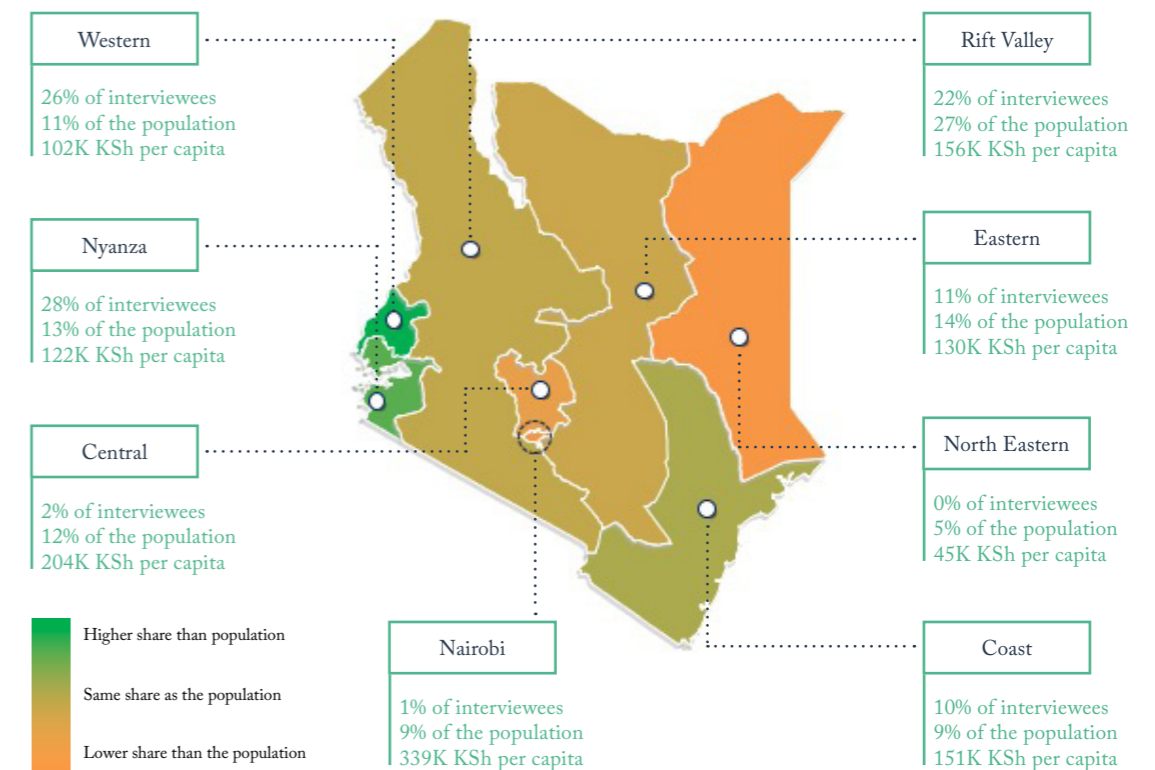


Figure 4: Map of the Kenyan Provinces - Sample share, Kenyan population share and average income by province; N=1001

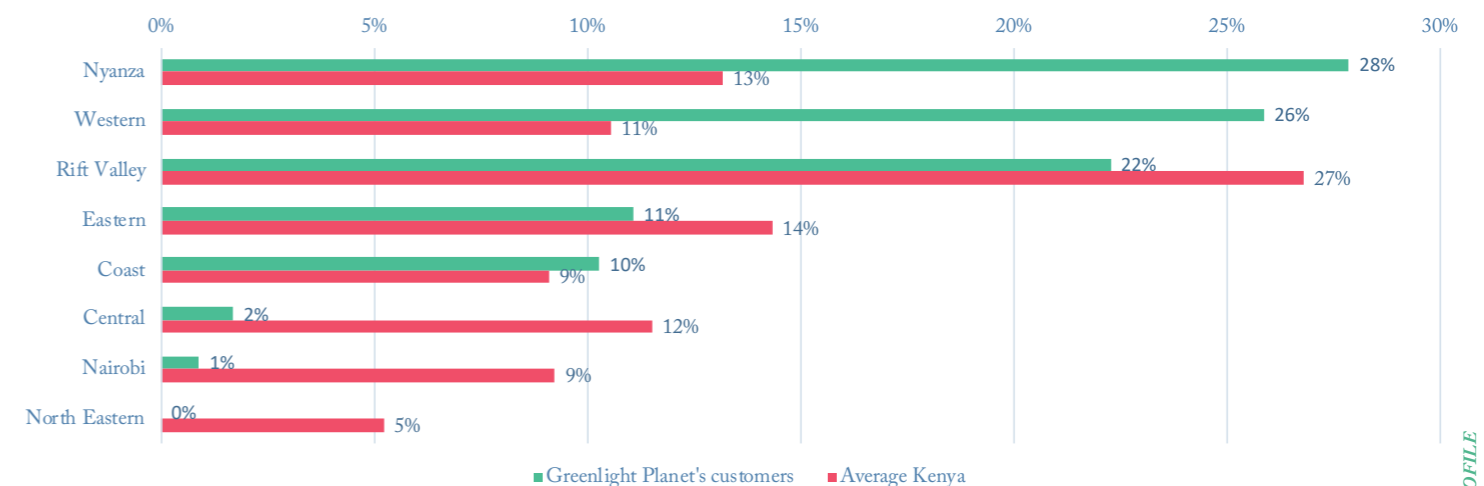


Figure 5: Share by province [share of respondents]; N=1001

⁴⁵ Kenyan Ministry of Energy. (2017). *The Kenya Off-Grid Solar Access Project (KOSAP)*.

Income level

The households' income level is derived from the Poverty Probability Index (2015) methodology.⁴⁶ Households below USD 3.20 per person per day represent 49% of the sample of customers of Greenlight Planet. Households between USD 3.20 and USD 5.50 per person per day represent 28% of the sample. Finally, households above USD 5.50 per person per day represent 24% of the sample.

This is very much in line with the Kenyan distribution of income among the population⁴⁷, where 47% (+2% in our sample) of the population lives below USD 3.20 per day, 25% (+3%) of the population lives between USD 3.20 and 5.50, and 29% (-5%) of the population lives above USD 5.50 per day. As a result, Greenlight Planet's SHS are reaching a proportionate mix of the Kenyan population.

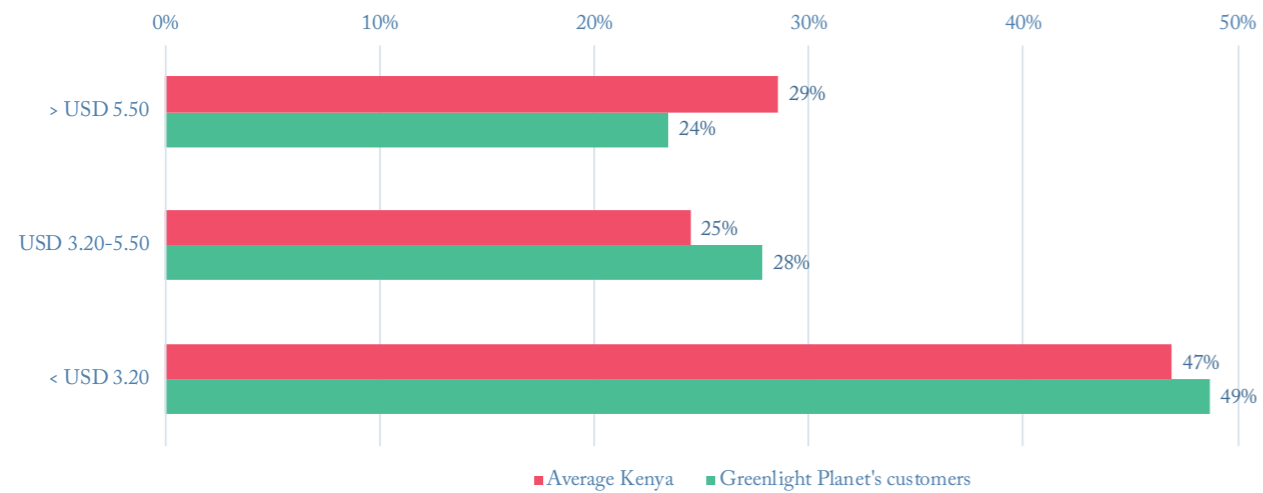
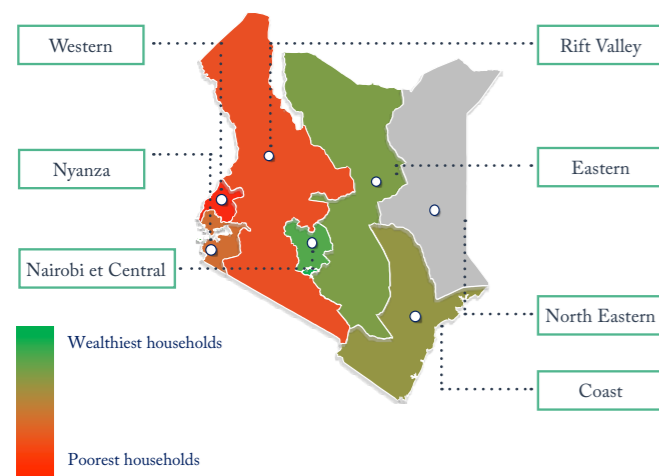


Figure 6: Income Distribution based on the PPI; N=1001

Other research initiatives exploring the reach of off-grid solar show similar penetration rates. In the Acumen⁴⁸ (2017) energy impact report, 35% of beneficiaries live on less than USD 3.10 per day, 38% live on between USD 3.10 and 6.00 per day, and 27% lives on more than USD 6.00 per day. In the GOGLA (2019)⁴⁹ East Africa report, 59% of

the customers reported earnings below USD 3.20 per day, 22% between USD 3.20 and USD 5.50 and 19% over USD 5.50. However, these two reports differ from this research in their methodology and geographical scope which limits the comparability of the data.⁵⁰

Sample of respondents



Kenyan population

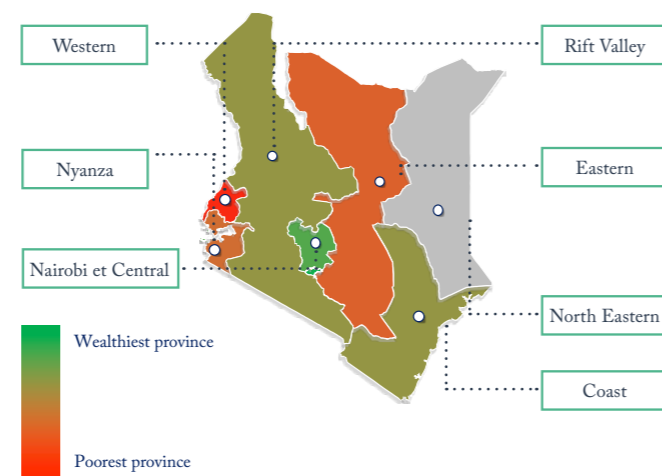


Figure 8: Map of relative income level by province of sample of respondents and Kenyan population; N=1001⁵¹

⁴⁶ See Introduction – Methodology for more details.

⁴⁷ Kenyan Poverty Probability Index. (2015).

⁴⁸ Acumen. (2017). *Energy Impact Report*.

⁴⁹ GOGLA. (2019). *Powering Opportunity in East Africa: Proving Off-Grid Solar is a Power Tool for Change*.

⁵⁰ Acumen's research covers solar companies in Ghana, Haiti, India, Kenya, Nigeria, Pakistan, Rwanda, Senegal, Sierra Leone, Tanzania and Uganda; GOGLA's research covers solar companies in Rwanda, Kenya, Uganda, Tanzania and Mozambique.

⁵¹ The income level of the sample of respondents is computed using the PPI[®] methodology by province, while the income level of the Kenyan population is computed as gross national income per capita by province.

Are SHS reaching the poorest in Kenya?

The analysis of the USD 1.00 and USD 1.90 poverty lines shows a different picture. When focusing on households below the 1.90 poverty line, we can observe that the sample share overlaps to a high extent with the share of the population, at 17% and 18% respectively. Nevertheless, this is not the case for the USD 1.00 poverty line.

The share of households in our customer sample that earn below USD 1.00 per day is 2.8%, which is in relative terms below the average share of the Kenyan population under this poverty line, at 4.5%. All in all, the analysis shows that the households that do not reach the value of minimum needs⁵² (earn below USD 1.00 per day) are the most difficult to engage as customers. Reaching the lowest earning 4.5% of the Kenyan population remains a challenge.

These results are not surprising as the Sun King Home 60 and Home 120 are mid-range PAYGo products in Greenlight Planet's portfolio. Greenlight Planet has a broad range of products with price points varying from approx. \$8 to \$500 allowing the company to cater to a wide array of needs and budgets. Through affordable products, including solar lanterns sold on a cash or PAYGo

basis, Greenlight Planet endeavours to reach low-income customers:

"Most players don't reach the Bottom of the Pyramid as much as we do. The truth is that it is hard to reach lower income consumers. You need to go to the small towns and villages, not only on the market day, but to have a presence in the community the rest of the time. It's not bad that some of our competitors don't reach as far into rural areas as we do, they just have a different business model. We serve who we can while running a financially viable business, and we are absolutely interested in and committed to reaching the hardest to reach areas."

Radhika Thakkar – Vice President
Corporate Affairs - Greenlight Planet

"Comparing Sun King product prices to the cost of other inefficient energy options that low-income households use, our price points are well within reach for these households. For example, our Sun King Easy Buy Lanterns are as low as Ksh 15 a day compared to Kerosene in Kenya which is approximately Ksh 100 per litre. Our Sun King lanterns provide access to cleaner energy to households who may not be able to afford Solar home systems."

Naomi Kioi – Africa Marketing
Leader - Greenlight Planet

This challenge is recognised by other players in the market:

"I would say it's true, the poorest are often not reached. The markets are served by all the companies but then reaching the more underserved, it's an affordability issue. Subsidies are needed."

Joane Kayibanda – Head of
Operations Kenya - BBOX

The government of Kenya and the World Bank have understood this and KOSAP has been put in place to help private sector companies serve the unserved in the 14 poorest counties:

"Everybody wants to reach these rural customers but to be able to get there, you first needed to reach the low-hanging fruits as a springboard. Result Base financing helped leap-frog us into rural areas with ENDEV and now KOSAP."

Itotia Njagi – Lighting Africa
Program Manager – IFC

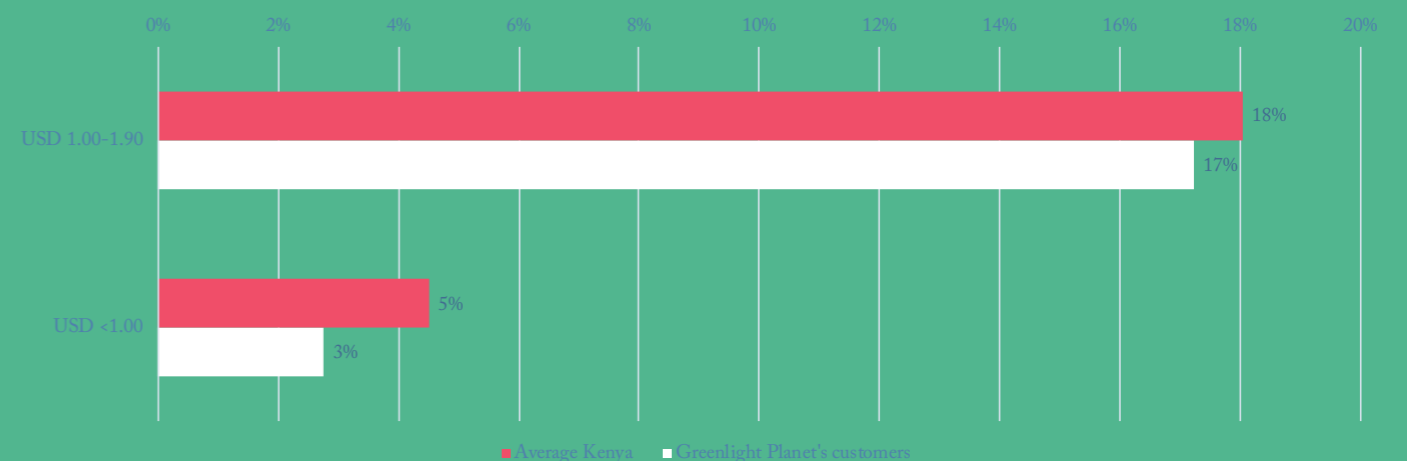


Figure 7: Income distribution based on the PPI, focus on lowest poverty lines; N=1001

⁵² World Bank. (2018). *Poverty and Shared Prosperity*.

Meanwhile, the customer sample's income level and the population income level by province are overall aligned. Only the Rift Valley and the Eastern Provinces show differences compared to our sample: The Rift Valley is the third province in terms of income in Kenya, and the sixth in our sample; meanwhile, the Eastern province is the fifth in terms of income in Kenya, and the third in our sample. The North Eastern province, which has no presence in our sample, has also been omitted from the assessment of the Kenyan population to allow a clean comparison.

Main source of income

Almost half of the households interviewed (40%) rely on agriculture as their main source of income. Agriculture is followed by general services⁵³ (15%), restauration and other food services (10%) and construction (7%).

The income distribution of agricultural households differs from the distribution of non-agricultural households, as agricultural households are generally poorer: 55% of agricultural households live on less than USD 3.20 per day, compared to 44% of non-agricultural ones; moreover, 18% earn over USD 5.50 per day, compared to 27% of non-agricultural households. This analysis holds when we include provinces as a control variable.⁵⁴

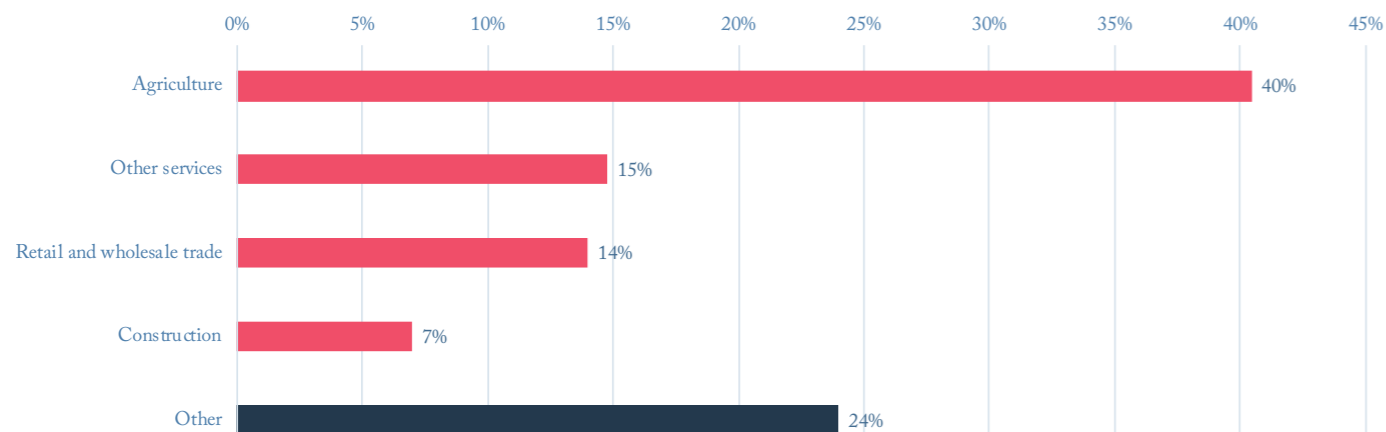


Figure 9: Main source of income [share of respondents], N=1001

Therefore, the units differ. The relative income level has thus been computed as a rank of provinces from 1 (richest province), to 7 (poorest province). The North Eastern province has been excluded, as there is no share of respondents living there.

⁵³ Other services include all services except grocery shops/stall, other retail and wholesale trade, restauration and other food services, mobile money agent and seamstress/tailoring.

⁵⁴ Nairobi, Central and North Eastern excluded

PRODUCT PREFERENCES

Type of product

Almost three quarters of households in the sample (74%) own the 6Wp product, compared to the one quarter that owns the 12Wp product (26%). Only 11% of the interviewees have fully repaid the system. This is relevant to contextualize some of the subsequent analyses, as very few customers have actually experienced the benefits of a SHS without the weekly costs attributed to it.

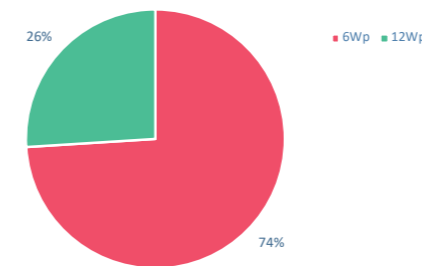


Figure 10: Type of product [share of respondents]; N=1001

Differences in the income distribution can be found between the owners of the 6Wp and 12Wp product, as owners of the 12Wp product are on average richer. 51% of owners of the 6Wp product, compared to 43% of owners of the 12Wp product, earn below USD 3.20 per day. Additionally, 22% of owners of the 6Wp product, compared to 28% of owners of the 12Wp product, earn above USD 5.50 per day.

Finally, 77% of the households report that the Sun King SHS was the first solar product they acquired. Among the 23% remaining, three-quarters (75%) upgraded their solar product (e.g. from a solar lantern, or a smaller SHS), 16% already owned a similar product, and 9% previously owned a larger solar product. All in all, Sun King's products seem to be a point of entry onto the solar energy staircase.

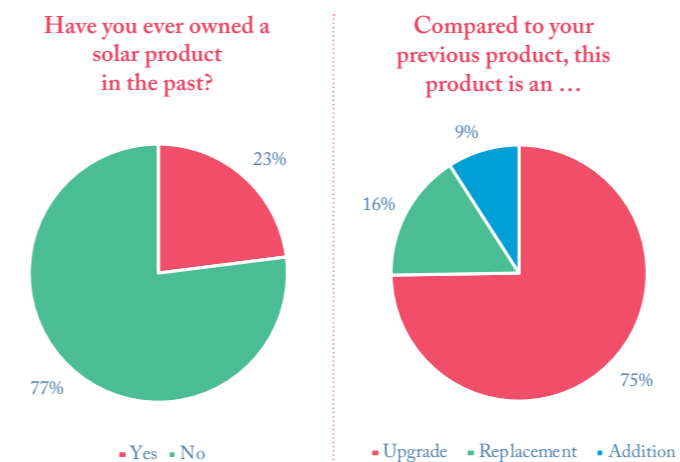


Figure 11: Previous solar product; N=1001

Figure 12: Type of previous solar product; N=228

Payment preferences

Almost two thirds of households (64%) would not have purchased the product if having to pay the full amount upfront, based on their current finances. This analysis is used as a proxy estimation of the value-added of PAYGo (through the Sun King EasyBuy platform) payment methods in solar home systems, which clearly "targets a significant market gap"⁵⁵. The share of households that would not have purchased is consistent across product sizes, with 64% for the 6Wp system and 65% for the 12Wp system. Furthermore, low-income households are slightly more likely to need PAYGo to purchase their product. 67% of households under USD 3.20 per day would not have bought their SHS without the PAYGo fees, compared to 62% and 58% respectively of the households that earn USD 3.20-5.50 and more than USD 5.50 per day.

Reasons to purchase a solar home system

For nearly two thirds of customers, the main reason to purchase a solar home system was obtaining a reliable access to light (with 64% of households mentioning it among the first four reasons to buy the product). Meanwhile, the second most common reason mentioned was improved light quality compared to the previous source of light (with 28% of households), and the third most common reason was the price and affordability of SHS (with 27% of households). A possible explanation for this distribution is the size and purpose of Greenlight Planet's SHS: these products are, above all, targeting the basic needs of lighting under strict budget constraints. Households purchasing drivers are very similar across both 6Wp and 12Wp products, with access and quality of light being the key elements sought after.

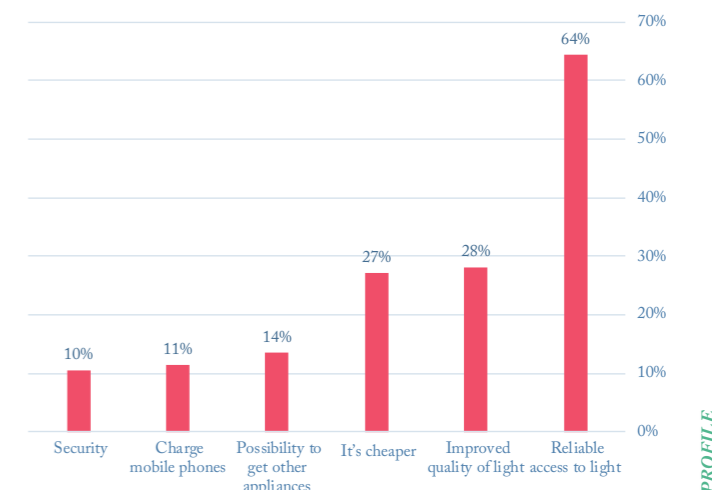


Figure 13: Purchasing drivers for solar home systems [share of respondents]; N=1001

⁵⁵ CGAP. (2018). Strange Beasts – Making Sense of PAYGo Solar Business Models.

Reasons to purchase a Sun King product

21% of households chose the Sun King product because of the brightness of its lights, 16% because they were influenced by an acquaintance and 14% because of the work of the salesperson that sold it to them. Other reasons such as the affordability (12%), reputation (10%) and durability of the systems (9%) were next in line.

Word-of-mouth has played a key role in driving sales of off-grid solutions as early adopters encouraged their acquaintances to follow their lead:

“At the start, some customers had a negative assumption of the value for money of solar but now it is better understood. Word-to-mouth and seeing customers use the product has really driven demand.” Douglas Gavala – Strategy & Research Manager – d.light

The high rate of customers mentioning the efforts of sales agents can be in part attributed to Greenlight Planet’s extensive distribution network of around 3,000 active agents in Kenya that reaches deep into target areas.⁵⁶

“Our Energy Officers (sales agents) create a community where they live. Some have been with us for more than 5 years. They are recruited from the local people in the village, and they build trust with the community.”

Victor Agandi – East Africa Business Leader – Greenlight Planet

When looking at the differences between households that own the 6Wp compared to the 12Wp product, it is interesting to highlight changes in the prioritisation. Influence from both close acquaintances and salespeople is highest by 12Wp owners, with 22% and 17% respectively, compared to 14% and 12% for 6Wp owners. Moreover, while 13% of 6Wp owners mention the price as the highest priority, only 8% of the 12Wp owners do so.

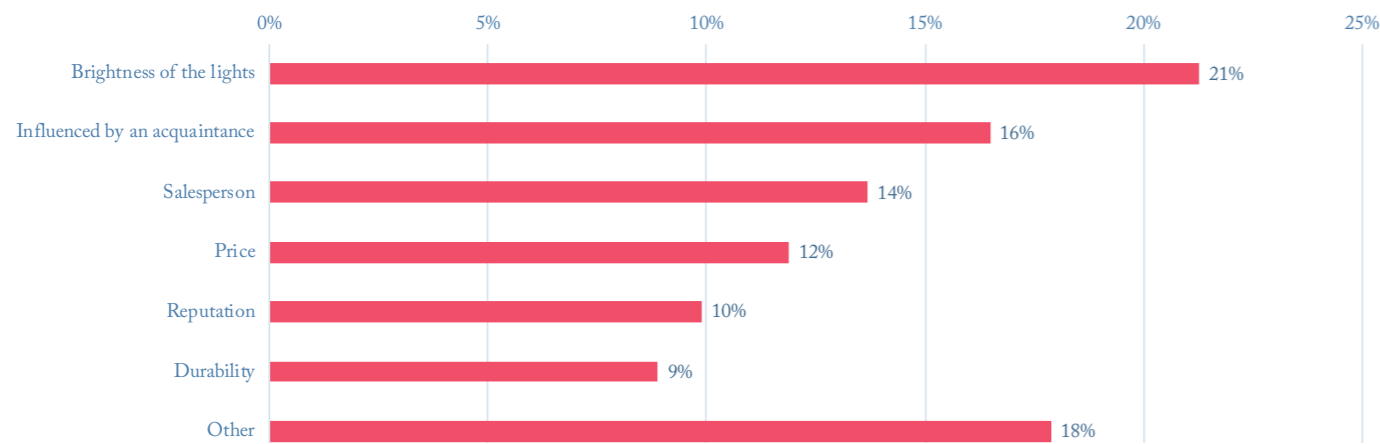


Figure 14: Purchasing drivers for Sun King [share of respondents]; N=1001



⁵⁶ An active agent is an agent that has sold one unit in the last 30 days

PRODUCT USAGE

The majority of the households report using the system only for home use (95%). The remaining households use it for home use and business use (3%), or only for business use (2%). This is unsurprising as these products are intended for home use. Previous research by GOGLA in East Africa had shown higher rates of business use (21%).⁵⁷ The lower rate of business use in this research may be explained by the system sizes involved but also by the focus on Kenya. Indeed, Kenya has a significantly higher electrification rate (64%)⁵⁸ than other East African countries⁵⁹ that may have an impact on usage of SHS for business:

“Solar home systems continue to be the quickest and most affordable path to electricity access for those without in rural areas. While in some rural areas the grid has been able to serve some business centres, only a few nearby households in many cases get connected to this grid network, underscoring the fact that Solar Home Systems will have a role to play within an integrated energy mix for the foreseeable future.” Patrick Tonui – East Africa Regional Representative – GOGLA

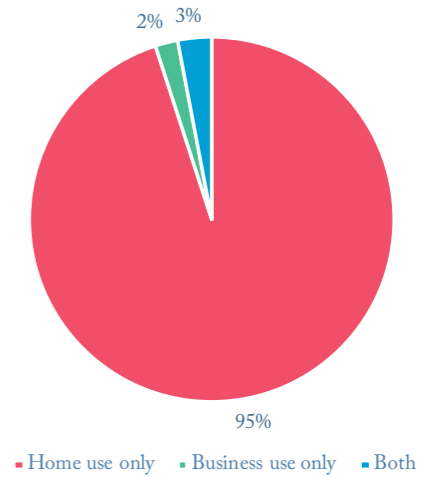


Figure 15: Core use of the solar product [share of respondents]; N=1001

Deep diving into the functions of the system at home, 95% of households mention having more light at night for home duties as one of the four main functions of the SHS. This is followed by charging a private phone, helping children to do homework and using appliances, being mentioned by 44%, 24% and 19% of households respectively.

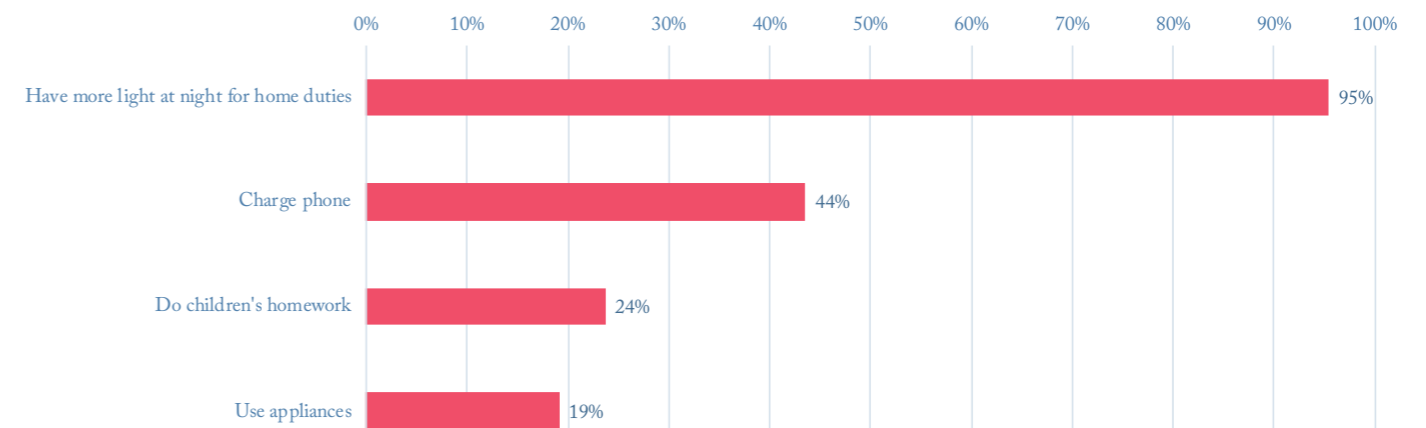


Figure 16: Main function of the SHS at home [share of respondents]; N=1001

We have deliberately not included the figures related to the business use of the SHS due to the high margin of error.

⁵⁷ GOGLA. (2019). “Powering Opportunity in East Africa : Proving Off-Grid Solar is a Power Tool for Change”.

⁵⁸ World Bank Data. (2017).

⁵⁹ World Bank Data. (2017). *Sub-Saharan Africa electrification rate 45%, Rwanda 34%, Tanzania 33%, Uganda 22%.*

What do consumers use the additional hours of light for?

To better understand product usage, we asked these customers what they do with the extra time with light provided by the SHS (which will be quantified in section III. Net Socio-Economic Impact). The additional time is primarily spent on helping with home duties (28%) and helping children with homework (28%). Both usage at home and how these additional hours are spent do not vary significantly between the owners of the 6Wp and 12Wp products.

One of the main benefits for households is the possibility to get multiple light points

allowing the household to conduct several activities requiring light at the same time such as homework for children and cooking:

“ Customers buy solar home systems because they need multiple light points and mobile charging. They want to enjoy the benefits of the solution from various points in their house or home. To be able to do several things with light at the same time means a need for multiple light points – cooking in the kitchen at the same time that children are studying in the living room and the bedroom is lit. Some of our systems also have an extra security light with a motion sensor as an add on. ”

Victor Agandi – East Africa Business Leader –
Greenlight Planet





III. NET SOCIO-ECONOMIC IMPACT

Solar home systems double the hours of light available to a household and help reduce more than 75% of total kerosene use. They also enable children to spend almost two extra hours per day doing homework. Owners feel healthier and safer thanks to the system. Households are also increasingly connected to information, as they double the time listening to the radio and thus to local news. Nevertheless, customers sometimes need to make adjustments to pay for their SHS. Half of the households have experienced cutting expenses on food or education at least once and one third have asked for money or a loan.⁶⁰

⁶⁰ All cross-analyses related to income levels and usage by gender of the household will be consolidated in Section IV. Impact Cross-Analysis.

LIGHT HOURS ⁶¹

Purchasing a SHS allows customers to benefit from more hours of light and increase its quality. Households get more than four (4.3) additional hours of light⁶² per day following the purchase of their SHS. In other words, they double the number of hours compared to the 4.2 hours that they had before acquiring the SHS.

The difference in hours of light is more pronounced in households that have owned the system longer. Households that acquired the system before 2019 report 4.7 additional hours of light on average, compared to 3.9 hours for households that acquired it in 2019. This could possibly demonstrate a learning curve effect that with time helps households to fully benefit from the SHS (e.g. by repositioning the photovoltaic panel or by restricting the charging of mobile phones and connected appliances to have more light).

Comparing the additional hours of light between the different provinces, we find divergences in impact.

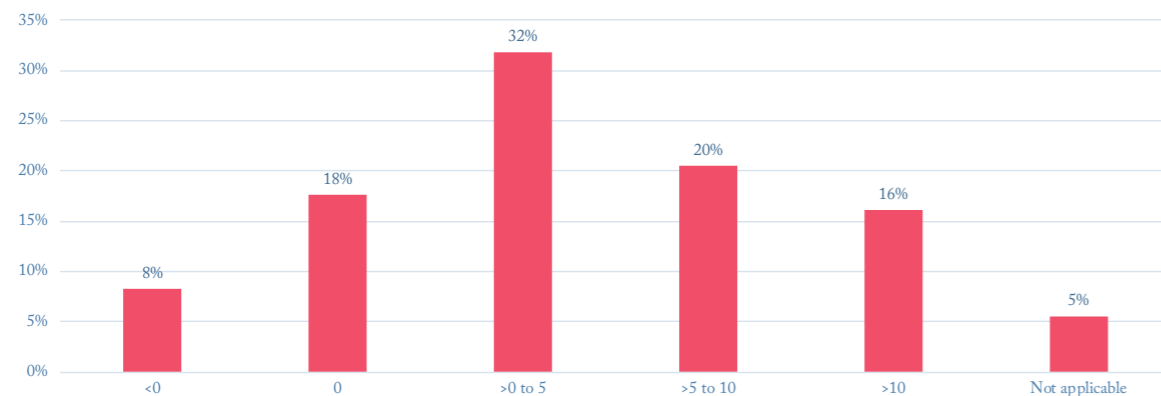


Figure 17: Additional hours of light per day [share of respondents]; N=1001



All in all, off-grid solar primarily contributes to SDG 7, the access to affordable and clean energy. Moreover, as reported by the UN⁶⁵, energy is an intermediate commodity, thus valued primarily for the services it enables. In relation to the SDGs, SDG 7 is primarily useful to help achieve other SDGs. As we will see in the following sections, beyond access to energy, SHS can make contributions in numerous other areas.

The Eastern and Western provinces showed the highest amount of additional light hours at 4.9 and 4.8 respectively. After dividing the provinces into two groups by income per capita⁶³, we realize that the households that reside in the four poorest provinces show an average of ~25 additional minutes of light more than households in the four wealthiest provinces. This could be due to the fact that customers in poorer provinces start, on average, with almost one hour of light less per day prior to acquiring the SHS compared to richer provinces.

There is no tangible difference between households that own the 6Wp product compared to the 12Wp product. It is important to mention that both 6Wp and 12Wp systems come with almost the same number of LEDs, while lumen output is the main differentiator.⁶⁴

KEROSENE REDUCTION

Solar home systems are helping reduce kerosene usage, and thus CO₂ emissions. Kerosene is a liquid fuel, similar in composition to diesel, obtained from the distillation of crude oil⁶⁶. On average, households that acquired a SHS eliminate 2.5 hours of kerosene light per lamp every day. Households owning the 12Wp product eliminate slightly more kerosene use than households owning the 6Wp one, with 2.6 hours less compared to 2.4 hours less of kerosene light per day. Households with more than six members reduce on average 2.7 hours of kerosene light, 0.7 hours more than households with less than six members (at 2.0 hours of kerosene light).

To complement this analysis, our research also focused on the number of kerosene lamps to estimate the total potential of kerosene elimination. When asked about kerosene lamps, households stop using on average 1.7 kerosene lamps after adopting the SHS, with only minor differences between owners of the 6Wp and owners of the 12Wp product and no tangible differences by province.

In total, after acquiring a SHS, households eliminate 75% of kerosene consumption for lighting from all lamps that they used previously.

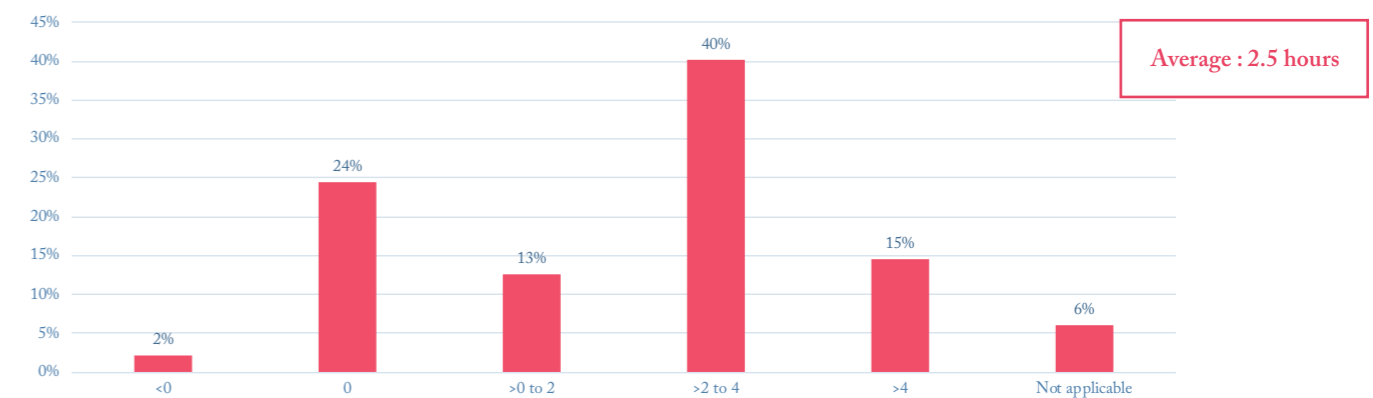


Figure 18: Reduction of hours of kerosene use for lighting [share of respondents]; N=1001

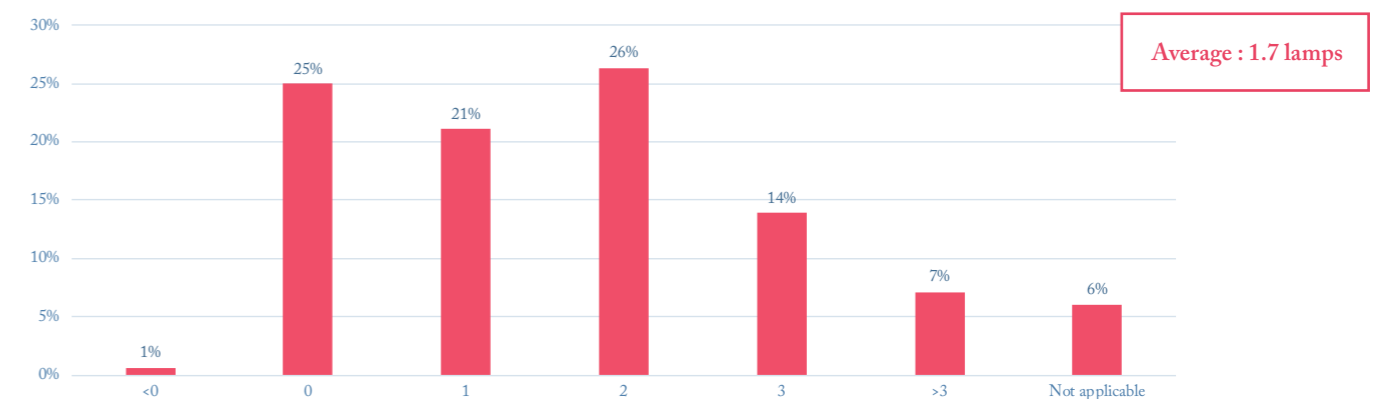


Figure 19: Number of kerosene lamps eliminated [share of respondents]; N=1001

Beyond hours of kerosene

A SHS not only represents a tangible increase in quantity of light, but also brightness. A standard kerosene lamp provides around 20 lumens⁶⁷, while Greenlight Planet's 6Wp and 12Wp systems provide

100 and 200 lumens per lamp respectively. According to ODI and GOGLA⁶⁸, SHS's additional brightness "allows activities that may not be conducted under dim light, adds to security, and can reduce eye

strain and illness". It is thus fundamental to explore the impact beyond additional hours of light and understand how regular household tasks are affected.

⁶¹ Light hours refer to hours of light from all light sources combined.

⁶² Additional hours of light from all light sources, before and after the acquisition of the SHS.

⁶³ Following the rationale that Eastern and Western are two of the three poorest provinces in our sample.

⁶⁴ Greenlight Planet's website: <https://www.greenlightplanet.com/>

⁶⁵ United Nations. (2019). Policy Brief #8. Accelerating SDG 7 Achievement. Policy Briefs in Support of the First SDG 7 Review at the UN High-Level Political Forum,

⁶⁶ World Health Organization (2006), Compendium of Chemical Hazards: Kerosene (Fuel Oil)

⁶⁷ GOGLA and ODI. (2016). *Accelerating access to electricity in Africa with off-grid solar.*

⁶⁸ GOGLA and ODI. (2016). *Accelerating access to electricity in Africa with off-grid solar.*



Kerosene is not only an inefficient source of lighting, it also exposes users to potentially severe health risks and pollutes the environment. Kerosene lamps and fumes can cause eye irritation, lung damage, and impact the health of unborn babies.⁶⁹ As we will see in the following sections on health and safety, kerosene reduction also contributes to SDG 3, good health and well-being. Furthermore, it also contributes to SDG 13, climate action. Within the SDG 13, it contributes to the indicator 13.1, thus to “strengthen the resilience and adaptive capacity to climate-related hazards and natural disasters of a country”.⁷⁰



EDUCATION

Solar home systems allow children to spend more time doing homework. Moreover, households report using the light helps children improve their grades. 91% of households with children report that their children spend more time doing homework because of the additional hours of light provided by the SHS. Among households where children work more during the evenings, 97% report their children are having higher grades. There are no significant differences between the owners of the 6Wp and the 12Wp product on both homework and grade improvement.

Do your children spend more time doing the homework thanks to the SHS?

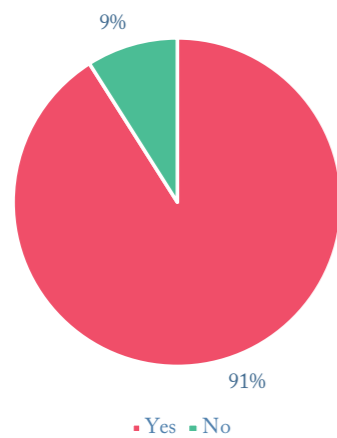


Figure 20: Children's homework [share of respondents]; N=943

If they spend more time, do their grades improve thanks to the SHS?

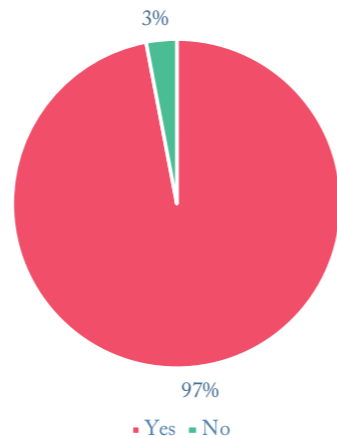


Figure 21: Children's grades [share of respondents]; N=854

Going one step further to calculate the impact, households see their children work almost two additional hours per day on their homework thanks to the adoption of the SHS (an additional 1h51 on average per day). This is true for both the owners of the 6Wp and the 12Wp product, with no tangible differences between system sizes. Households living in the four poorest provinces see a slightly higher increase in time spent on homework after acquiring the SHS: an additional 1h57, compared to 1h41 for children living in the four

wealthiest provinces. Hours of additional light also impacts the time children devote to homework: households with 0-5 additional hours of light see an increase of 1h47, while households with six or more additional hours of light see an increase of 2h01 in time devoted to homework per day.

⁶⁹ Lam et al. (2018). *Exposure Reductions Associated with Introduction of Solar Lamps to Kerosene Lamp-Using Households in Busia County, Kenya*, Indoor Air 2018, 28 (2), 218–227.

⁷⁰ United Nations (2017), Global indicator framework for the SDGs and targets of the 2030 Agenda for Sustainable Development

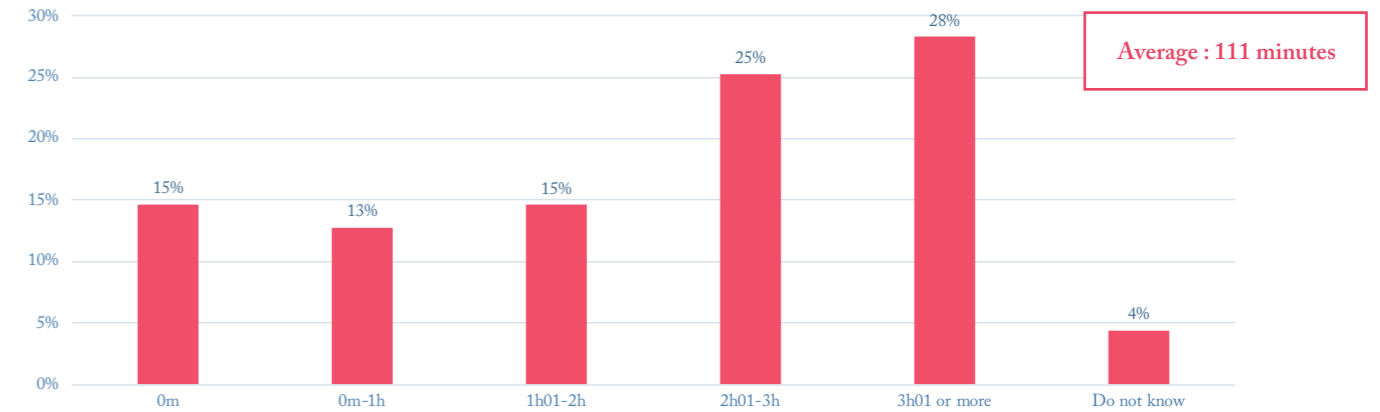


Figure 22: Additional homework time by household [share of respondents]; N=1001



Increasing the hours of homework and improving the grades of children through the adoption of solar can have a profound impact on their economic situation. According to the Global Partnership for Education⁷¹, 171 million people could be lifted out of extreme poverty if all children left school with basic reading skills. Furthermore, their research highlights that for each dollar invested in an additional year of schooling, earnings increase by USD 5 in low-income countries and USD 2.5 in lower-middle income countries. Overall, education can help explain half of the difference in growth rates between East Asia and Sub-Saharan Africa between 1965 and 2010. Off-grid solar can, therefore, help contribute to SDG 4, quality education, and indirectly to SDG 8, decent work and economic growth.



HEALTH

Health can also improve thanks to the adoption of SHS. 74% of households report feeling healthier thanks to their SHS. Among the main reasons why interviewees feel healthier, households report having less fumes in the house (41%), their eyes feeling less strain (16%) and family members coughing less often (12%).

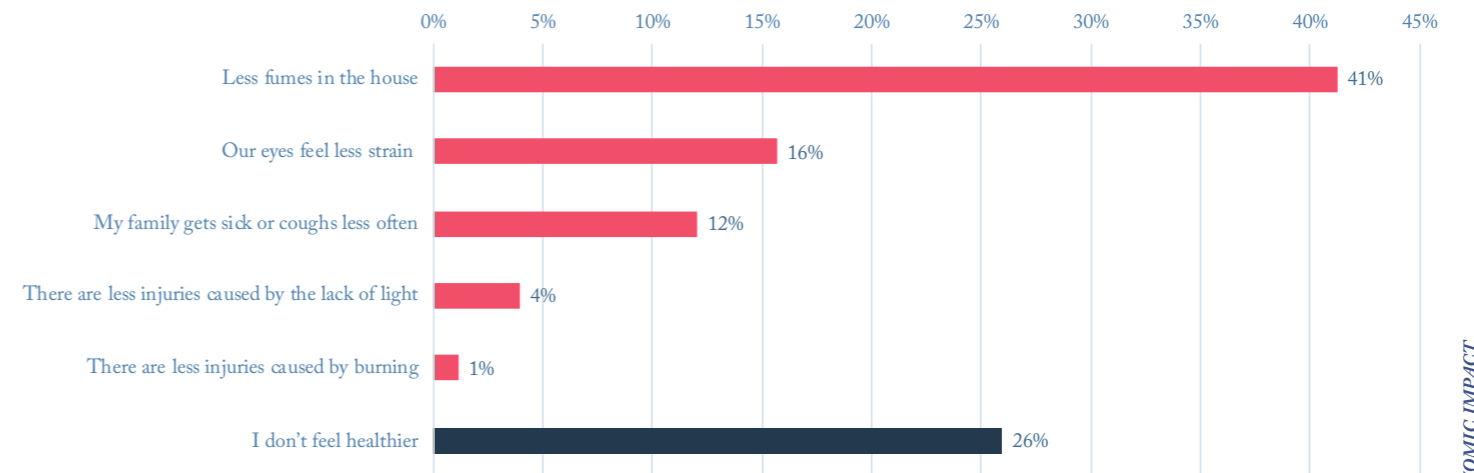


Figure 23: Health assessment of the household [share of respondents]; N=1001

⁷¹ Global Partnership for Education. (2016). 5 ways education can help end extreme poverty.

Impact of solar lighting on health when replacing kerosene

Previous research has shown that kerosene usage in households is a threat to people's health. They have also shown that reducing its usage leads to health benefits. This is most notably the case of previous research on solar lamp users in the Busia County in Kenya⁷². The eye symptoms associated with lamp use, including tired or itchy eyes when reading or studying, which were present on the majority of children and adult users interviewed, disappeared 12 months after changing to solar lighting use. This research also shows that kerosene is a strong indicator of disease risk, by using sensors to study exposure to particulate matter (PM2.5). Introducing solar

lanterns into the households led to a 70% decrease in exposure.⁷³

Other pieces of research, such as the study by Mills (2015)⁷⁴ from the Berkeley National Laboratory, shows that fuel-based lighting shows adverse health and safety risks in 33 countries, including burns, indoor air pollution, poisoning due to accidental ingestion of kerosene fuel by children, compromised visual health, and maternal health issues. Additionally, the study also reports that women and children are disproportionately impacted by the adverse effects of kerosene use.

Finally, a research authored by SolarAid (2014)⁷⁴ in Sub-Saharan Africa estimated the contribution of kerosene lamps to indoor pollution to be equivalent to smoking 170 cigarettes per year.

"Households that shift to Sun King products from kerosene report improvements in health of family members. The risk of fires is also greatly reduced within these households."

Naomi Kioi – Africa Marketing Leader - Greenlight Planet



Households that own the 6Wp product report more often that their health improved (76%), compared to households that own the 12Wp product (68%). However, this remains a difference in perception, as the share of households where at least one member had repetitive coughing at night is the same for 6Wp and 12Wp users (~30%). Additionally, households that reduce more than three hours of kerosene light feel slightly healthier than households that reduce less than three hours of kerosene (77% compared to 72%).⁷⁶



As a result, adopting a SHS decreases the probability of kerosene-related symptoms and diseases. This majorly improves the health and well-being in the household (SDG 3), which can boost productivity during work hours, indirectly contributing to decent work and economic growth (SDG 8)⁷⁷. Within SDG 3, it contributes primarily to the indicator 3.9, "by 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination".⁷⁸

SAFETY AND SECURITY

Households also feel safer thanks to the SHS. On average, 87% of the interviewees report feeling safer because of the system's usage. The most common reason mentioned is because it keeps robbers away from the house (34%), followed by the fact that they can reach home safely after dark (25%). These two reasons possibly refer to households that put a LED outside that provides lighting in front of their home. This is especially true in the case of the Home 120 which includes a motion sensor light that was specifically designed for this use. Other reasons include the fact that they can keep predators away from the house and from the livestock (15%),

and that they can go to the toilet safely during the night (8%). 92% of the households that own the 12Wp product report feeling safer, compared to 85% of the households that own the 6Wp product. This is likely due to the inclusion of motion sensor lights in the 12Wp product.

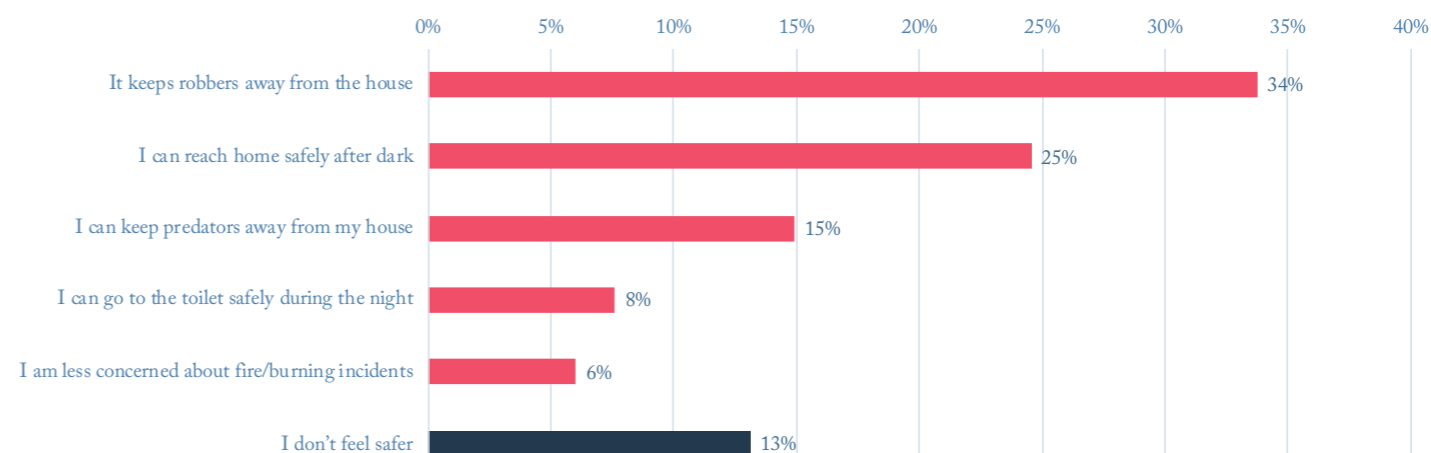


Figure 24: Safety perception [share of respondents]; N=1001



Warding off thieves, attackers and wild animals at night⁷⁹, and improving the safety in the household overall, adds to the contribution to SDG 3, namely to the good health and well-being of the household.

⁷² Lam et al. (2018). *Exposure Reductions Associated with Introduction of Solar Lamps to Kerosene Lamp-Using Households in Busia County, Kenya*, Indoor Air 2018, 28 (2), 218–227.

⁷³ A 70% decrease in exposure is in line with the 75% decrease in kerosene consumption illustrated in the previous section.

⁷⁴ Mills. (2015). *Identifying and reducing the health and safety impacts of fuel-based lighting*

⁷⁵ SolarAid. (2014). *Impact report*

⁷⁶ Threshold chosen based on the average of kerosene light hours reduced.

⁷⁷ SolarAid. (2015). *Kerosene subsidies – a hidden cost*.

⁷⁸ United Nations (2017), *Global indicator framework for the SDGs and targets of the 2030 Agenda for Sustainable Development*

⁷⁹ GOGLA. (2019). *Four ways tackling climate change is already boosting prosperity: Lessons from off-grid solar*.

FINANCIAL INCLUSION

17% of the interviewed households used mobile money for the first time because they acquired the solar product. The households did increase the amount of mobile money transactions on average, but only by one transaction per week.

This could presumably be the transaction to pay for the SHS fees. We also see little difference between different product sizes.

Financial inclusion in Kenya

In the context of Kenya, these results hardly seem surprising. In Kenya, nearly three in four adults have a mobile money account. In the recent Brookings Financial and Digital Inclusion Project (FDIP)⁸⁰, Kenya ranks 1st among 21 emerging economies

in enabling access to and usage of financial services among people excluded from formal finance. In other words, Kenya emerged as a recognized leader in financial inclusion. The share of the Kenyan population over 15 years old with access to a financial

account⁸¹ has increased vastly in recent years, from 42% in 2011 to 81% in 2017. Kenya's neighbour countries Uganda (59%), Tanzania (47%), Somalia (37%), Ethiopia (35%), Sudan (15%) and South Sudan (9%) have significantly lower access rates.⁸²

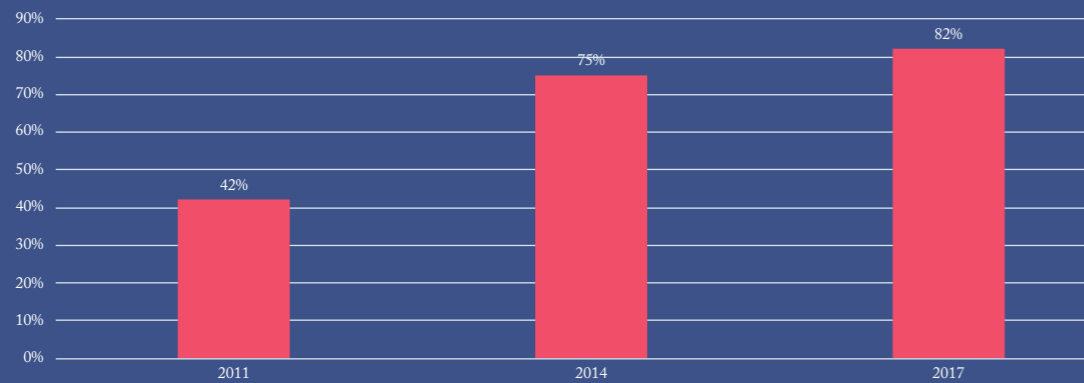


Figure 25: Access to a financial account in Kenya [share of the population over 15 years old]

High penetration of mobile money in Kenya helped build the PAYGo market:

"Relative to other markets, Kenya is not a challenging space because mobile money is so widely used,

customers are familiar with the product category, with the concept of PAYGo and with the off-grid brands."

Radhika Thakkar – Vice President Corporate Affairs – Greenlight Planet

ACCESS TO INFORMATION

Households see an almost twofold increase in weekly hours of radio following the adoption of the SHS. Households listen to 16 hours of radio per week after acquiring the SHS, seven hours more than before. 6Wp and 12Wp owners listen to almost the same number of hours of radio after acquiring the solar product. This is because close to 100% of systems come with a radio, regardless of the size of the product.

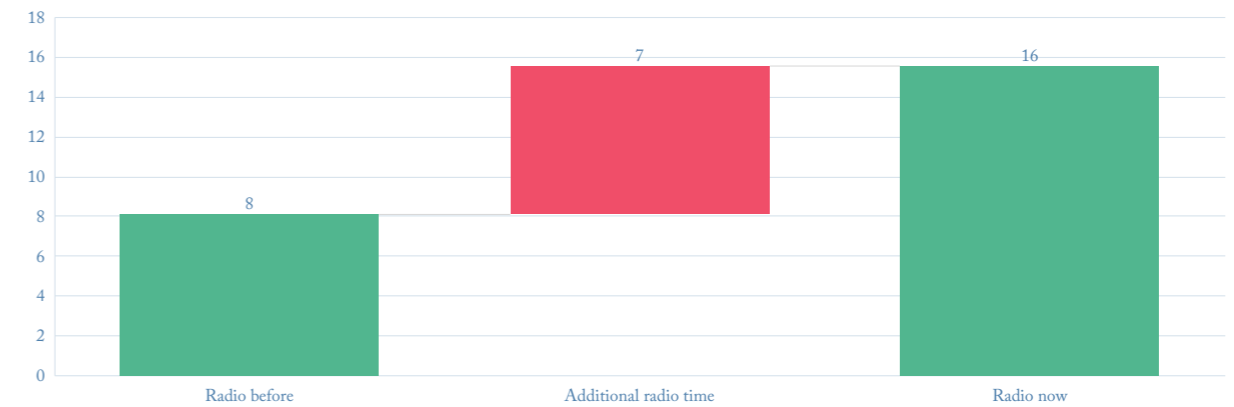


Figure 26: Hours of radio per week, before and after adoption [share of respondents]; N=1001

Listening to more radio is positively correlated to access to information, as households mostly listen to local news. 75% of households report local news to be one of the main four radio content they listen to. The second and third most popular contents are music and religious broadcasts (21 and 15% respectively). Local news, however, clearly remains the number one choice for households overall.

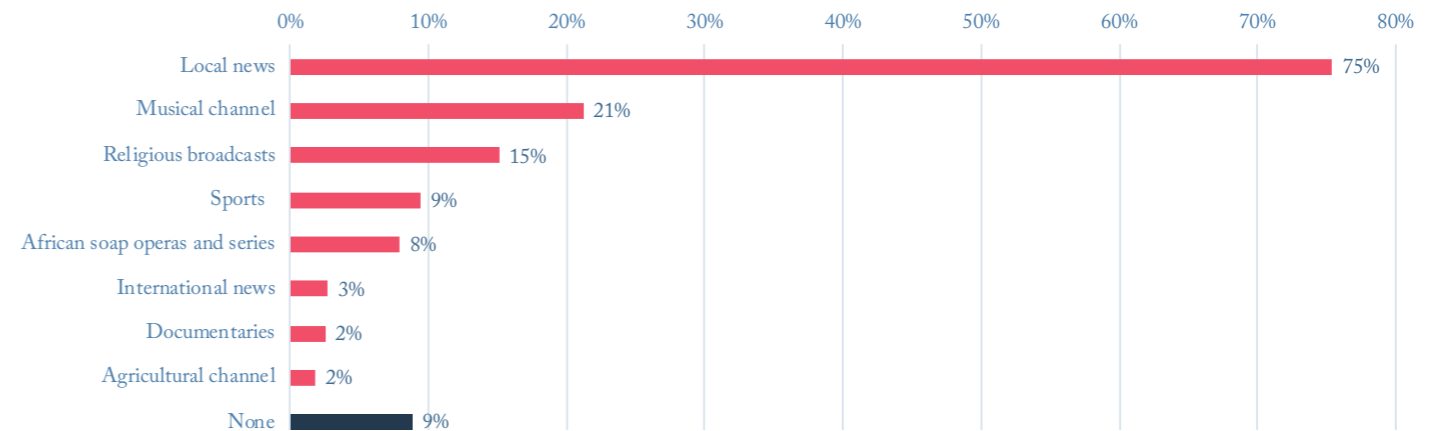


Figure 27: Content of radio and TV [share of respondents - multiple answers]; N=1001



As reported by the UNESCO⁸³, access to information is critical to achieve the Sustainable Development Goals. Through access to information, the population is empowered to make informed choices, effectively monitor and hold their government to account, and be aware of decisions affecting their lives. In particular, public access to information is linked to freedom of expression, which is vital to achieve peace, justice and strong institutions (SDG 16). In fact, the UN indicator 16.10⁸⁴, which is part of SDG 16, "ensures public access to information and protects fundamental freedoms, in accordance with national legislation and international agreements"⁸⁵.

⁸⁰ Lewis, Villasenor and West. (2017). *The 2017 Brookings Financial and Digital Inclusion Project Report – Building a Secure and Inclusive Global Financial Ecosystem*.

⁸¹ Denotes the percentage of respondents who report having an account at a bank or another type of financial institution (by themselves or together with someone else) or report personally using a mobile money service in the past 12 months.

⁸² World Bank. (2018). *Global Financial Inclusion Database*.

⁸³ UNESCO. (2019). *Monitoring and Reporting of SDG Indicator 16.10.2 – Access to Information*

⁸⁴ UNSTATS. (2017). *Indicator 16.10.2*

⁸⁵ United Nations (2017), *Global indicator framework for the SDGs and targets of the 2030 Agenda for Sustainable Development*

ADJUSTMENTS MADE BY CUSTOMERS

Liquidity constraints

Less than half of the households faced liquidity constraints in order to pay for the SHS fees (42%). In total, 36% of the households interviewed had to ask for a loan, either from a relative or friend to pay for the SHS (85% of the loans) or from a financial institution (15% of the loans). The remaining 6% faced other types of liquidity constraints.⁸⁶ Some studies in different sectors and regions report similar patterns: the CGAP⁸⁷, for example, reported in a study based on microcredits in India that as many as “one in every five borrowers reported higher obligations that they could reasonably afford”. Furthermore, according to the study, low-income households can resort to raise resources from friends and social networks, using smaller informal loans to repay old debt.

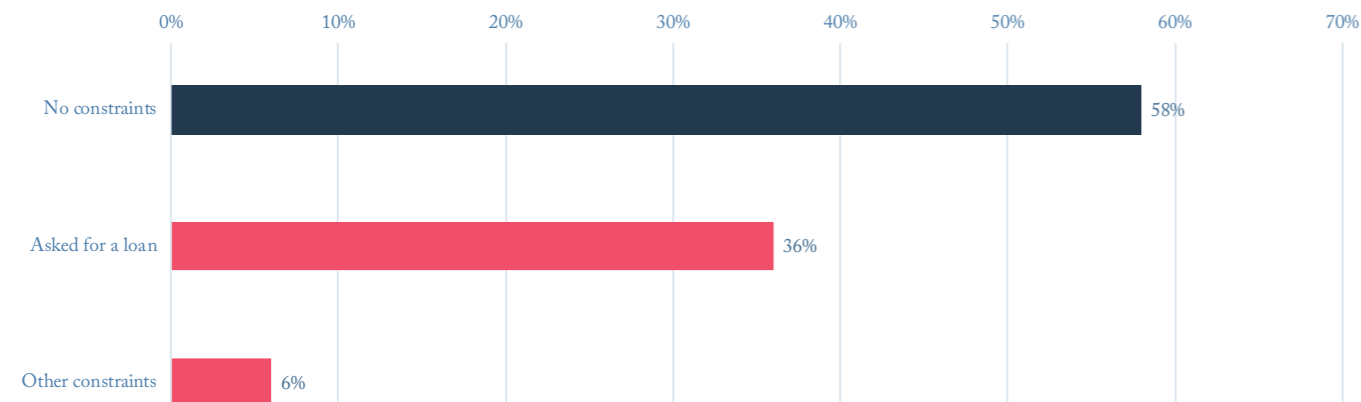


Figure 28: Liquidity constraints [share of respondents]; N=1001

There are tangible differences in the liquidity constraints faced by owners of the different systems. 66% of the owners of the 12Wp product report not having faced any liquidity constraints, compared to 55% of the 6Wp users. This is likely to be correlated with the income level of households that can afford the 12Wp product (as we will see in section IV). There are no visible differences in liquidity constraints following the province of origin of the household.

Financial adjustments

Approximately half of the households have experienced spending less money on food, clothes or education at least once to pay for their SHS. 58% of households disclose that they have spent less money on food, 48% of the households disclose that they spent less on clothes, 47% of the households

have skipped a meal to pay for the SHS and 41% of the households have spent less on education. Other categories where expenditure adjustments were made include airtime (56%), cosmetics (43%) and alcohol (26%).

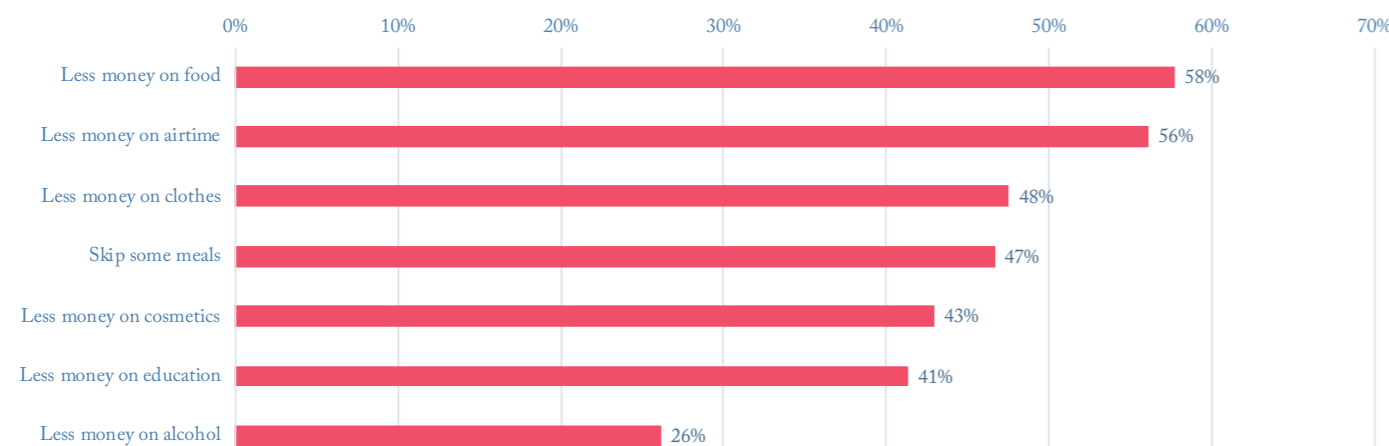


Figure 29: Expenditure adjustments [share of respondents]; N=1001

⁸⁶ Other types of liquidity constraints include defaulting on a house payment, defaulting on a phone bill and saving less money.

⁸⁷ CGAP. (2017). *All's Well That Repays Well? Not Necessarily*.

It is important to clarify that our research tools do not allow us to measure the recurrence and severity of these behaviours. For example, we cannot estimate if the food sacrifices occurred in luxury foods or vital staple foods for the population. As a reference, research performed by the CGAP in Kenya and Tanzania⁸⁸ on digital credits shows that 50% of borrowers in Kenya report they have repaid a loan late, and 20% report that they have reduced food purchases to repay for a loan. In the CGAP study, a significant percentage of borrowers said they did not fully understand the cost and fees associated with the loan, and therefore it was harder to make good borrowing decisions. A different CGAP⁸⁹ study in India suggests that lowering consumption or postponing essential expenses to repay a micro loan in due time are common coping mechanisms. Nevertheless, there are no elements in the literature that would allow us to benchmark precisely and with a comparable sample the impact highlighted in this study. Additional research would be interesting to go beyond microloans and focus on comparing the behaviour of PAYGo customers to behaviours relative to other big expenditures including school fees, medical expenses, funeral fees and purchases of other assets such as bicycles.

Households that own the 12Wp product are less likely to make adjustments than owners of the 6Wp product. On average, the percentage of 12Wp owners that makes sacrifices is seven percentage points below the percentage for 6Wp owners. Using food expenditure as an example, 61% of owners of the 6Wp product have had to spend less money on

food, compared to 50% of owners of the 12Wp product (11 percentage points below). This is despite the bigger product being more expensive. We will thus explore these findings accounting for the correlation with income level in section IV. This is in line with CGAP's⁹⁰ research on digital credit, where the data shows that Tanzania's poorest and most rural regions have the highest late repayment and default rates.

Payment Flexibility

Under the PAYGo model, Greenlight Planet offers significant flexibility to repay. This is essential in making SHS affordable for low-income and rural customers and for customers with irregular income. Flexibility lightens the burden of repayment for customers and also provides them with the possibility to only pay for the system when they need to use it.

Greenlight Planet follow-up with customers that are struggling to pay to make sure they are able to collect their payments while providing

them with the possibility to pay only when they are able to do so. Customers who struggle to pay or no longer want their product are also given the opportunity to return it.

“Customers who have not paid for 5 days receive a call from the agent that sold them the product. Then, if they still don't pay, after 19 days they receive a call from our call centre. After that they get SMS reminders until they have paid or are repossessed” – Pierandrea Renna – Global Program Manager – Greenlight Planet

“We repossess after 180 days of no payments from the customers, and customers are contacted to understand their ability and willingness to make future payments before the actual repossession. We also do voluntary repossessions for customers who no longer want the product.” – Sarah Mijabi – Global Risk Leader – Greenlight Planet

⁸⁸ CGAP. (2018). *It's Time to Slow Digital Credit's Growth in East Africa* – based on 2100 customer phone interviews.

⁸⁹ CGAP. (2017). *All's Well That Repays Well? Not Necessarily*.

⁹⁰ CGAP. (2018). *It's Time to Slow Digital Credit's Growth in East Africa* – based on 2100 customer phone interviews.

Reported feelings of stress

A high share of households report experiencing stress or sleeping less at night since purchasing the solar home system. 47% report at some point having experienced stress caused by the payments, 33% report having slept less at night, and 29% report having experienced loss of energy or appetite and irritability. This is very similar for owners of the 6Wp and 12Wp product. Additionally, households that already finished repaying reported on average less stress (eight percentage points) and less problems sleeping (six percentage points) than the households still paying. This could potentially show that once households have finished repaying their system, their perspective changes for the better. The severity and recurrence cannot be estimated following this preliminary level of analysis.

Despite the overview of challenges faced by the customers described above, a very small share expressed having ever regretted their decision to buy the SHS (8%). This hints to the fact that the majority of households believe the various positive impacts offset the adjustments and constraints mentioned above.

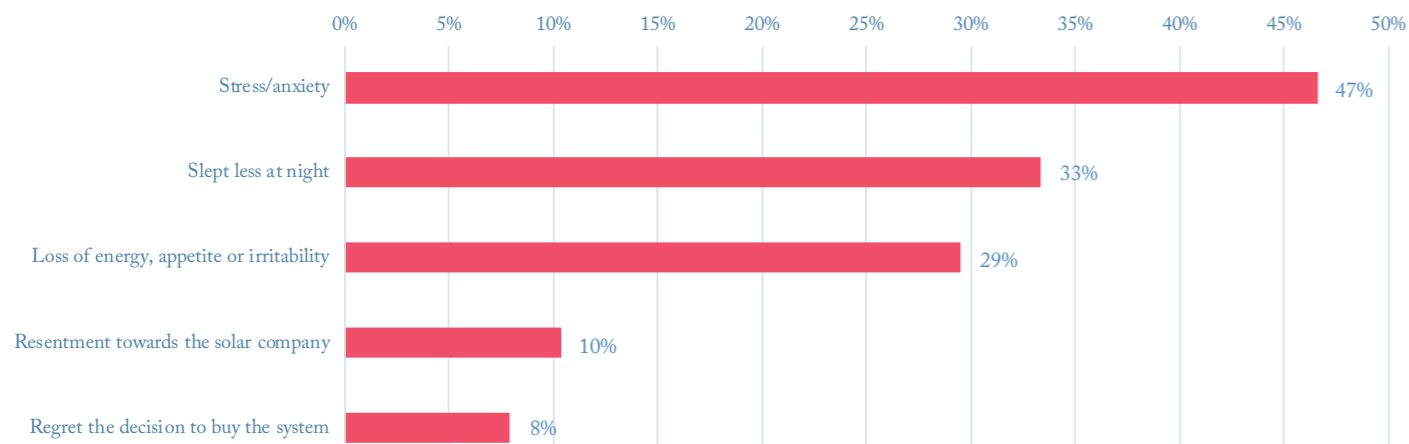



Figure 30: Psychological symptoms [share of respondents]; N=1001





IMPACT CROSS- ANALYSIS

Socio-economic impact is spread among most households, and in particular among poorer households and households where women are the main users of the system. Poorer households have more additional light and reduce more kerosene than richer households do. Moreover, children in poorer households spend more time on homework.. However, poorer households are more likely to report spending less on food and education and are more likely to experience stress or sleep less at night. Households where women are the main users of the system are more likely to report additional benefits from the solar home systems, in terms of light, kerosene reduction, education and access to information.

REACHING LOW-INCOME HOUSEHOLDS

In the previous section we have identified and highlighted differences in impact based on factors that could be correlated with income, such as wealth of the region or size of the SHS. In this section, we aim at understanding the degree in which the various impact indicators differ between poorer and richer households.

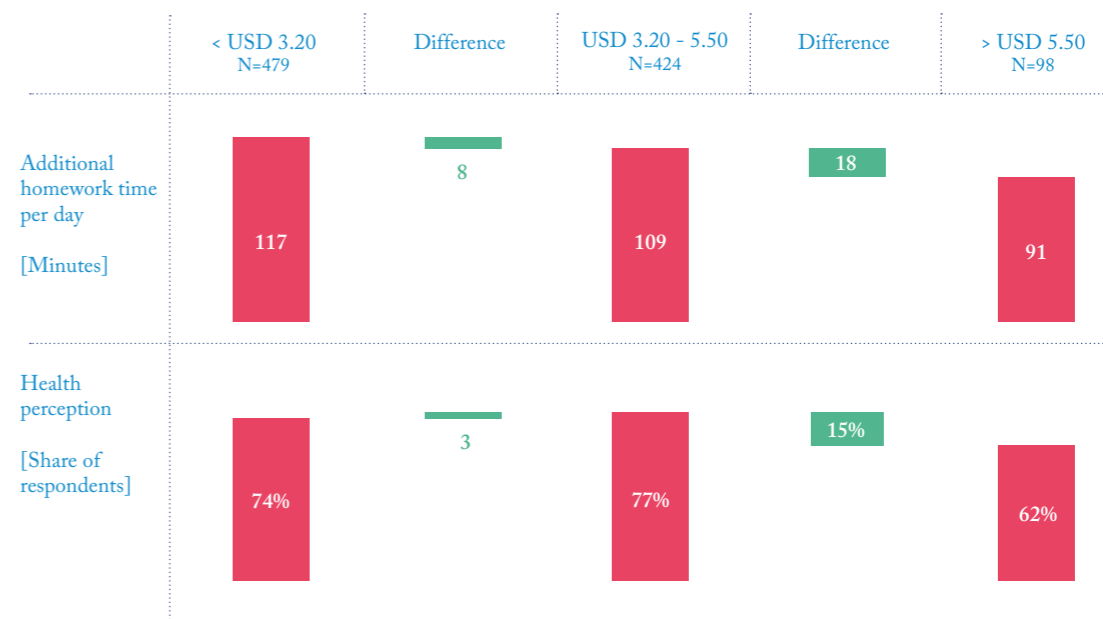
Overall, socio-economic impact manifests across all income levels. Households living below USD 3.20 per day (poverty line in low-middle-income countries⁹¹) and between USD 3.20 and 5.50 per day (poverty line in upper-middle-income countries) had a bigger increase in hours of light of 1.3 hours per day more than households that earn over USD 5.50. It is nevertheless important to mention that households over USD 5.50 had one more hour of light per day before buying the SHS compared to households with lower income.

Poorer households are also more likely to reduce kerosene usage. On average, households below USD 3.20 and between USD 3.20 and 5.50 reduce 2.5 and 2.6 hours of kerosene lighting per day, compared to 1.7 hours of kerosene for households over the USD 5.50 poverty line. This is also likely in part because the richer households relied less on kerosene before acquiring the SHS. 41% of households over USD 5.50 did not report using any kerosene light before

acquiring the SHS, compared to 19% of households between USD 3.20 and 5.50 and 11% of households below USD 3.20 per day. When it comes to kerosene lamps, households below USD 3.20 per day also eliminate the most. They eliminate 1.9 lamps, compared to 1.6 lamps for households between USD 3.20 and 5.50, and 1.5 lamps for households above USD 5.50 per day.

Overall, the impact in terms of education and health is different across income-levels. Children in poorer households are seeing their share of time devoted to homework increase more than other households. On average, children in households that earn below USD 3.20 per day increase their homework time 26 minutes, or 29%, more than households above USD 5.50 per day. Perception of health is also impacted by the income level of the household. Households below USD 3.20 and between USD 3.20 and 5.50 per day feel 74% and 77% healthier respectively after acquiring their SHS. This is on average 17% higher than households over the USD 5.50 line, where 62% of them feel healthier. 32% of households below USD 3.20 had at least one member of the household cough repetitively at night, compared to 24% of richer households above USD 5.50 per day. Regarding safety perception, all households seem to perceive the increase in safety in a similar way.

Figure 31: Impact across income levels



All in all, according to the UN Policy Report #8⁹², reducing the global disparity in energy is key to reducing income inequalities and inequalities in other dimensions such as rural/urban income disparities. A lack of adequate, reliable and affordable supplies of modern energy disproportionately impacts rural and poor communities and limits its productive opportunities, enterprise growth and employment, exacerbating income inequality and persistent poverty. As a result, clean and affordable solar energy is making a contribution to the SDG 10, reduced inequalities.

Deep diving into the adjustments made by customers, we see the differences become more pronounced. Overall, 66% of households above USD 5.50 have never faced liquidity problems. This is 15 percentage points higher than the 51% of households below USD 3.20 per day that have not faced liquidity problems. If the necessity to ask for liquidity arrived, poorer households most often rely on loans by relatives or friends. In comparison, the share of households above USD 5.50 that asked for a loan from a financial institution is ~50-75% higher than in the other two groups.

Adjustments of expenses seem less common in richer households. While 70% of the households below USD 3.20 had to face reduced expenses on food at least once, only 52% and 32% of households between USD 3.20 and 5.50 and above USD 5.50 faced these circumstances. Similar conclusions can be extracted from the other coping mechanisms.

We would like to highlight:

49% of households below USD 3.20 spent less ON EDUCATION compared to 27% of the households above USD 5.50

56% of households below USD 3.20 spent less ON CLOTHES compared to 31% of the households above USD 5.50

44% of households below USD 3.20 skipped MEALS compared to 17% of the households above USD 5.50

⁹¹ World Bank. (2018). *Poverty and Shared Prosperity*.

⁹² United Nations. (2019). Policy Brief #8. Accelerating SDG 7 Achievement. Policy Briefs in Support of the First SDG 7 Review at the UN High-Level Political Forum,

Finally, poorer households feel more stress. Households under USD 3.20 suffer more stress (+19%), sleep less at night (+27%) and have lost more energy or appetite (+21%) than households over USD 5.50.

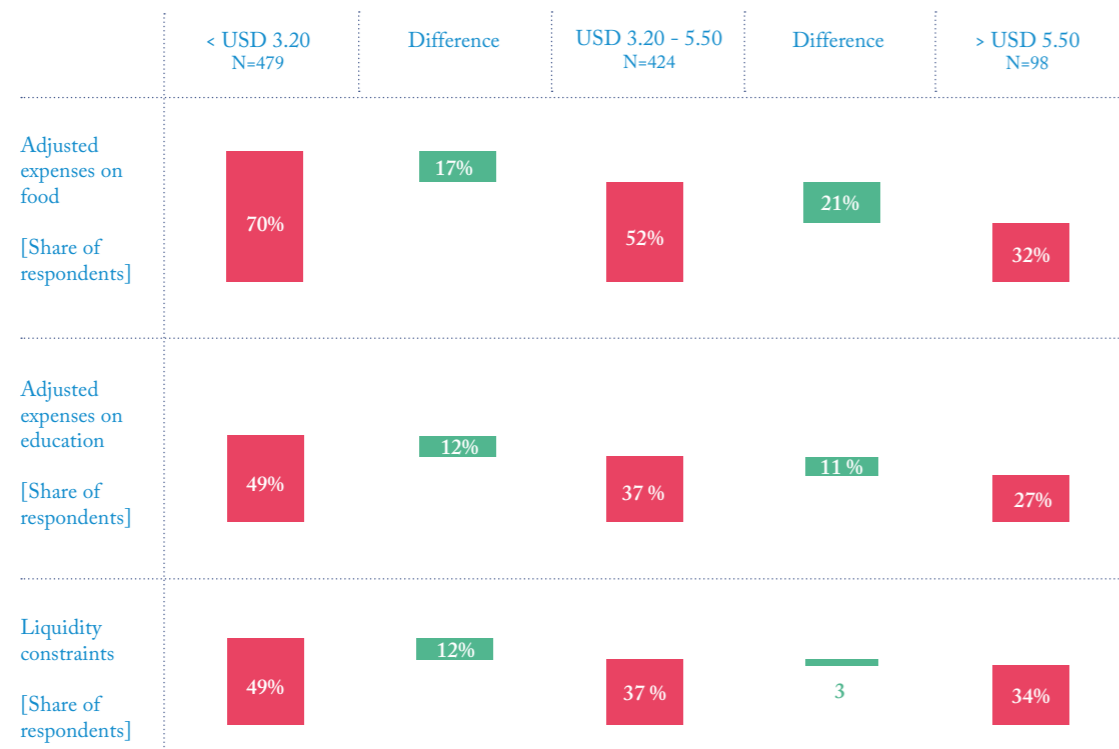


Figure 32: Adjustments of expenses across income levels⁹³

Despite poorer households making more adjustments to repay the SHS, the share of households that regret the decision to buy is equally low across all income levels. Despite a heavier financial burden, the vast majority of poorer households show a net positive perception of SHS.

REACHING WOMEN

Households where women are the main users of the SHS report more additional hours of light per day, less time using kerosene and fewer kerosene lamps. Households where women use the system most benefit on average from 38 more minutes of light per day, 36 less minutes of kerosene light per day and use one kerosene lamp less per household after adopting the SHS compared to households where men are the main users of the system. On average, female users thus reduce 2.6x more kerosene from all lamps than households with mostly male users.

In addition, children living in households where women are the primary users of the system work 20 additional minutes per day on their homework. Children in households where men use the system the most add one hour and 22 minutes to their daily school work at home, compared to one hour and 42 minutes in households where women are the main users. Focusing on access to information, households where women are the main users of the system report listening to the radio 5 hours more per week (or a 38% increase) than households where men report being the main users.⁹⁴

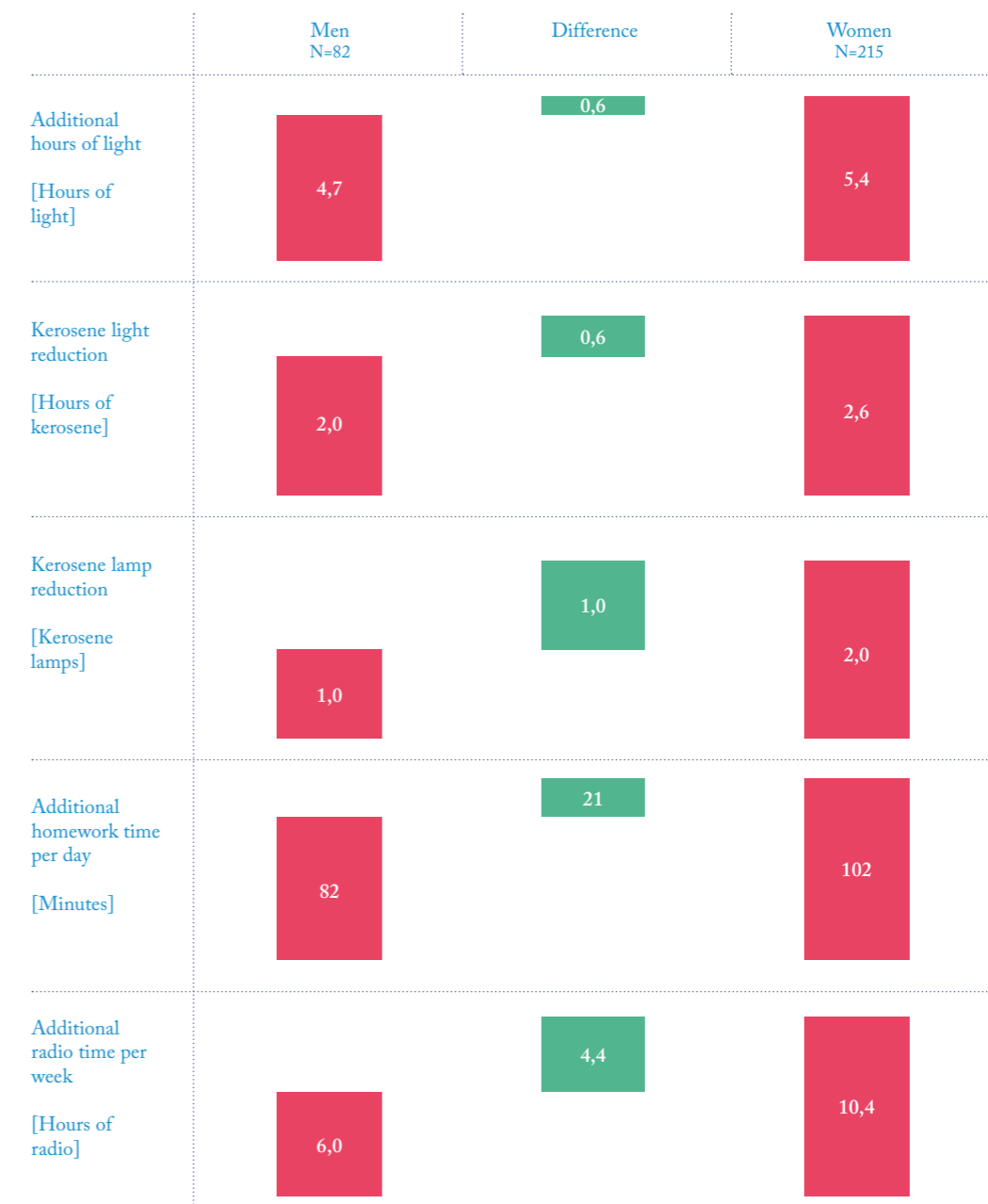


Figure 33: Impact by main user of the system

⁹³ Not all challenges faced by customers have been included in the Figure.

⁹⁴ The insights of the analysis by the gender of the respondent and the gender of the person responsible to acquire the system show the same patterns as the main user of the system

Women empowerment and solar powered electricity access

Energy poverty is not gender neutral, as women disproportionately bear the burden of electricity poverty:



The lower a country's electricity access rate, the higher its gender inequality index.⁹⁵



- 85% of the 2 million deaths caused annually by indoor air pollution from burning fuels are death of women and children.⁹⁶



- After disasters and conflicts, women and children in internally displaced person camps that are unlit at night face increased risks of assault and sexual and gender-based violence.⁹⁷

In a research that examined the gendered implications of various types of electricity access in rural Kenya⁹⁸, it was shown that men dominate within the grid, mini-grids and private suppliers, leaving an important potential for women's empowerment untapped. According to the study, because men tend to have a moral right to make major decisions, decentralised systems of electricity supply (such as SHS) provide women with more agency than fixed connections and high subscriptions fees.



According to the United Nations⁹⁹, clean energy access is critical for women's health, education and productive activities, and contributes to reducing inequality for women. One of the reasons for this is that most women spend more time than men using and collecting fuel for the home. Improving energy access thus improves the conditions in which unpaid labour and care work are carried out.



⁹⁵ Deloitte University Press. (2014). *Women, Energy and Economic Empowerment*.

⁹⁶ UNDP and World Health Organization. (2009). *The energy access situation in developing countries*.

⁹⁷ UNHCR. (2015). *UNHCR Emergency Handbook*.

⁹⁸ Winther et al. (2018). *Solar powered electricity access: Implications for women's empowerment in rural Kenya*.

⁹⁹ United Nations. (2019). Policy Brief #8. Accelerating SDG 7 Achievement. Policy Briefs in Support of the First SDG 7 Review at the UN High-Level Political Forum,





CONCLUSION

This research brings forward relevant insights on the socio-economic impact of affordable SHS, their contribution to the electrification of low-income households and the impact of gender on usage. This piece examines not only traditional aspects of impact measurement in the literature on off-grid solar, but also includes insights on access to information and key challenges faced by customers. This research also aims at highlighting the contribution of small SHS to the sustainable development goals.

The vast majority of households report benefits from SHS usage

In most households, SHS make a significant difference in hours of light. Households report more than twice the amount of light time compared to what they had before acquiring the solar product. This helps reduce by more than 75% the hours of kerosene light and number of kerosene lamps that they used previously.

Affordable solar home systems are also enabling children to spend significantly more time doing homework. This triggers a positive impact on their grades. Overall, children

spend almost two extra hours per day on doing homework thanks to the additional light. Most respondents also feel both healthier and safer thanks to their SHS, as the reduced kerosene usage means less fumes in the house and the possibility to have a light outside helps them reach home safely after dark. Households also see the time spent listening to the radio double after acquiring the SHS, which enables customers to be better informed, mostly through more access to local news.

Households may need to make adjustments to repay their SHS, but the overall socio-economic benefit is positive

One third of households have asked for additional formal or informal loans to repay for their SHS. Additionally, around half of the households report having at least once spent less money on food, education, clothes or skipping some meals. Moreover, more than one third of households report having experienced stress or slept less at night because of the SHS repayment. Nevertheless, only a very small share of households regretted the decision to buy a SHS, thus hinting to a positive net socio-economic benefit.

Low-income households represent the largest share of customers and report most benefits from the SHS

The biggest group of customers earns below USD 3.20 per day. Not only is the share of respondents in poorer households the largest, but they are also more likely to report positive impacts from using the SHS. Households earning less than USD 3.20 per day have 1.3 more additional light hours and reduce one additional kerosene hour from each lamp per day than households that earn more than USD 5.50 per day. Moreover, children in poorer households (under the USD 3.20 poverty line), work on their homework 26 minutes more per day than richer households (above the

USD 5.50 poverty line) do thanks to the SHS. However, households that earn under 3.20 USD per day are also more likely to spend less money on food, clothes, or education to manage their payments for the SHS. They are also more likely to report experiencing stress or sleeping less at night than richer households.

Households where the main users are women report higher positive impacts

70% of the households reported both women and men to use the system equally. Among the rest, women came next as the main users of the system, with a share more than twice the size of households where only men are the main users. Moreover, households where women are the main users are more likely to report benefits from the system. Households where women are the primary users of the system obtain 40 more minutes of additional light per day and reduce 35 more minutes of kerosene from every lamp compared to households where men are the main users.

This research has brought forward new insights that would greatly benefit from further examination. Additional research would be helpful in better understanding the impact of SHS on low-income households. Future studies could analyse the following topics: an in-depth financial cost-benefit analysis of small solar home systems, the impact of subsidies for PAYGo SHS on reaching the underserved, the extent of financial adjustments made by customers when acquiring a solar product through a PAYGo scheme, or the role of stand-alone off-grid products in businesses and how their impact can be maximized.

All in all, affordable solar home systems are helping to reach low-income households across Kenya and having a positive impact on their users beyond access to energy (SDG 7). They also contribute to good health and well-being (SDG 3), quality education (SDG 4), gender equality (SDG 5), decent work and economic growth (SDG 8), reduced inequalities (SDG 10), climate action (SDG 13) and peace, justice and strong institutions (SDG 16), making them a powerful tool to contribute to the SDG 2030 agenda.





ANNEX

Data collection:



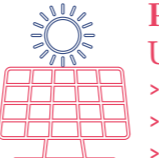



The 1,001 interviews were phone-based. All questions during the interview had closed answers and some had the option to provide additional input, marked as “Other”. Data collection was conducted using tablets and adapted software to ensure traceability and enable monitoring, allowing Altai Consulting to swiftly review and address any irregularities. The quality of the interviews was further ensured through quality control by both Sagaci Research and Altai Consulting. Interviews were checked via the recording whenever necessary. Any irregularities or suspected irregularities led to a dismissal. Where relevant, further cleaning was conducted by Altai Consulting to ensure the robustness of the data.

Data cleaning:

- **Other:**
For several questions, the response “Other” was a possibility for the interviewee and led to a follow-up question in order to obtain a specific response. Wherever possible, these answers were recoded into existing pre-coded responses or, if a sufficient number of specified answers addressed the same point, a new answer was generated.
- **Inconsistencies:**
Whenever a combination of answers was initially perceived as illogical and the recording of the interview did not provide any clarification, the interview was dismissed.

Survey instrument:

The survey was comprised of 58 questions, with the following structure:

 <p>Part 1: General: > Identifying a user of Greenlight Planet’s SHS</p>	 <p>Part 2: Demographics: > Gender > Main source of income > Household size > Geographic location</p>	 <p>Part 3: System Usage: > Solar ladder > Home use > Business use</p>
 <p>Part 4: Net Socio-Economic Impact: > Light > Kerosene > Education > Health > Safety > Financial inclusion > Access to information > Challenges faced by customers</p>	 <p>Part 5: Purchasing Drivers</p>	 <p>Part 6: Economic and Social Level</p>

The survey instrument is available to researchers upon request.

Phone-based data collection:

Phone-based data collection was preferred to SMS and IVR methodologies as these are not ideal for this type of research. However, they can be useful under other circumstances. There are two reasons why the study was phone-based:

First, the spoken form with involvement of an interviewer increases the accuracy of the answers. This survey had an average length of more than 20 minutes and included sensitive questions. This gives the opportunity to establish a human connection and answer clarifying questions, which our interviewers have been trained to handle. Furthermore, our sample, with a high share of low-income customers is likely to have low literacy rates and lower technological capabilities, which could pose a problem when using SMS or IVR technologies. All in all, the increase in quality and quantity of response rates of phone interviews decreases substantially the sample bias that could be occasioned by SMS or IVR.

Second, this research required a tailor-made survey. Different societal contexts in the respondents’ sample requires a non-standardized approach. Additionally, there was the need for open-ended questions, including the option in most questions to include an answer that is not in the range of preliminary answers envisioned.

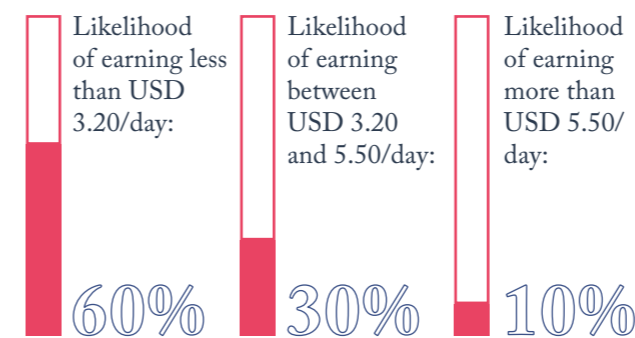
Example 1: Questions about the income earned by the household or the level of education could be more likely to receive an answer when asked by a human being over the phone.

Example 2: Additionally, a sample segment could be misrepresented if clients with certain characteristics are unable to use or feel uncomfortable using SMS/IVR.

Income level estimation:

The income distribution of the sample of customers was calculated using the Poverty Probability Index (PPI®). The PPI® is a statistical poverty measurement tool comprising ten questions or indicators about a household’s characteristics and asset ownership. These ten questions have been tailored to the Kenyan population in 2015, so that the statistical results reflect the reality on the ground. Answers are scored to compute the likelihood that the household is living below a given poverty line. With the PPI®, organizations can identify the clients, customers, or employees who are most likely to be poor, integrating objective poverty data into their assessments.

Poverty lines include the USD 1.00, 1.90, 3.20, 5.50, and 8.00/day. This is an example of the output delivered using the PPI® methodology:



and assume that is the income range of the household. Six income ranges were assessed for this computation, to improve the accuracy: Less than USD 1.00, USD 1.00-1.90, USD 1.90-3.20, USD 3.20-5.50, USD 5.50 to 8.00 and more than USD 8.00. Therefore, the expectation is that the probability function follows on average a standard normal distribution with a fixed mean that is represented by the range with the highest probability. Both positive and negative deviations of the mean even out on average. In our example above, the household would be attributed to the range of less than USD 3.20/day.

The PPI® methodology allows a very interesting application using aggregated data. All sample probabilities taken together can be computed as the share of the sample in each of the income ranges.

The final income ranges that have been chosen for this research are less than USD 3.20 per day, between 3.20 and 5.50 USD per day and more than USD 5.50 per day, based on 2011 purchasing power parities. These are three of the poverty lines developed by the World Bank. These poverty lines are defined by the World Bank as standards among lower- and upper-middle income countries respectively. They are designed to complement the USD 1.90 international poverty line. The reason for the substitution in this paper is because the World Bank data suggest that the rapid gains against extreme poverty have not been matched by reductions in the number of people living below these relatively higher levels of income.¹⁰⁰

In addition to that, this research adjusted the methodology to be able to derive the income level range for one individual household. This is paramount in order to disaggregate impact data by income level of the households. Our research paper will take the income range that yields the highest probability

¹⁰⁰ World Bank. (2018). *Poverty and Shared Prosperity*.

Income by county:

In this research we will include information at a sub-national level. This particular analysis will allow us to analyse trends based on the geographic location of the household. In this research we will focus on the subdivision by provinces, not counties.

To contextualize, the 2010 constitution in Kenya introduces a subdivision into 47 counties whose size and boundaries are based on the previously defined districts of Kenya. This followed a re-organisation of Kenya's national administration, as counties were now integrated into a new national administration with the national government posting county commissioners to represent all counties.

However, a subdivision of 47 counties in a sample of 1,001 customers makes it difficult to extract any sizeable and statistically significant conclusions. As a result, we have decided to group the counties into eight provinces, which are based on the subdivision that preceded the counties. The data displayed on provinces will nevertheless come from an analysis by county. Therefore, these provinces are only to be interpreted as a grouping to achieve more relevant insights and higher statistical significance.

In this research, we will make allusions to both counties' and provinces' average income level. The counties' average income level has been computed taking the gross county product in 2018/19 divided by the population in 2018. The gross county product is consistent with the published national GDP. GDP at a county level is measured using the production approach, which is the only analysis that yields data disaggregated at that level.

IMPACT MAPS

The following maps by province highlight impact distribution by province that is important for this research:

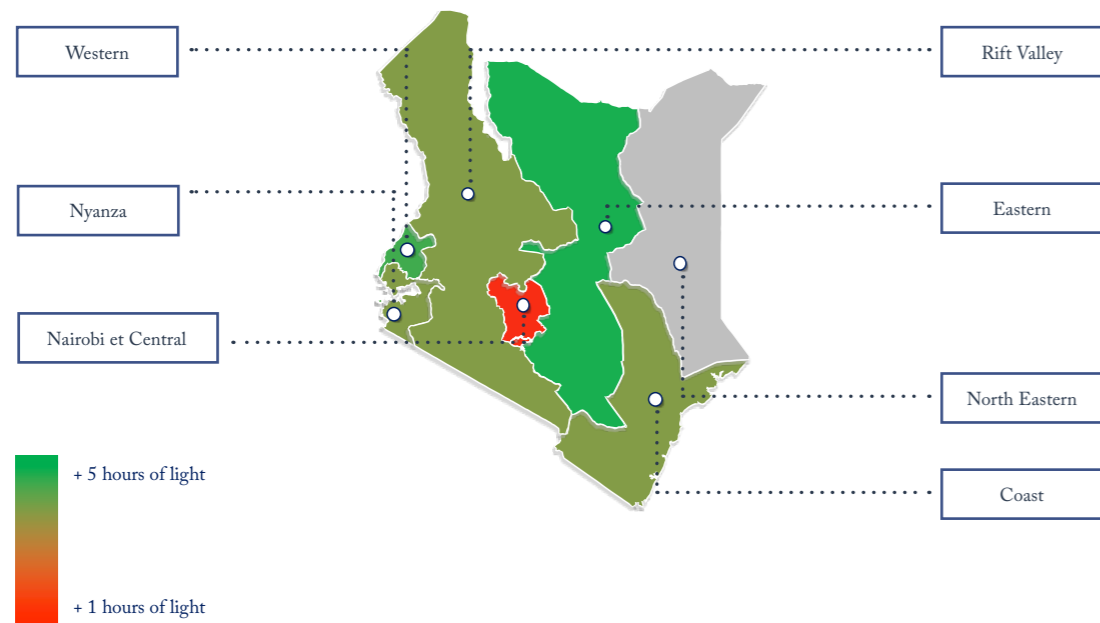


Figure 34: Impact by province - Additional hours of light; N=1001

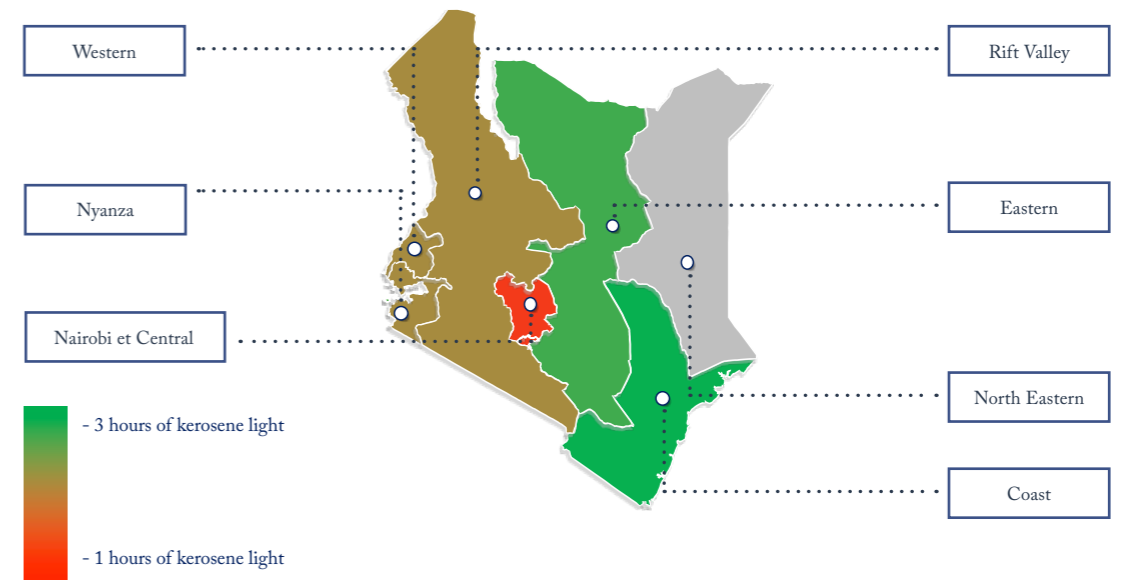


Figure 35: Impact by province - Kerosene light reduction; N=1001

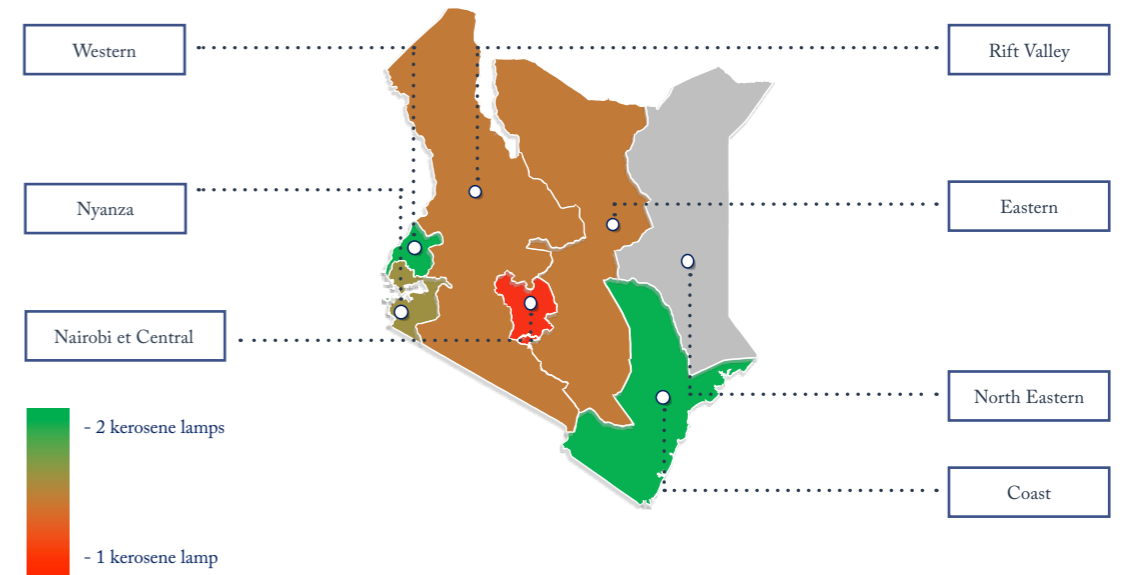


Figure 36: Impact by province - Kerosene lamp reduction; N=1001

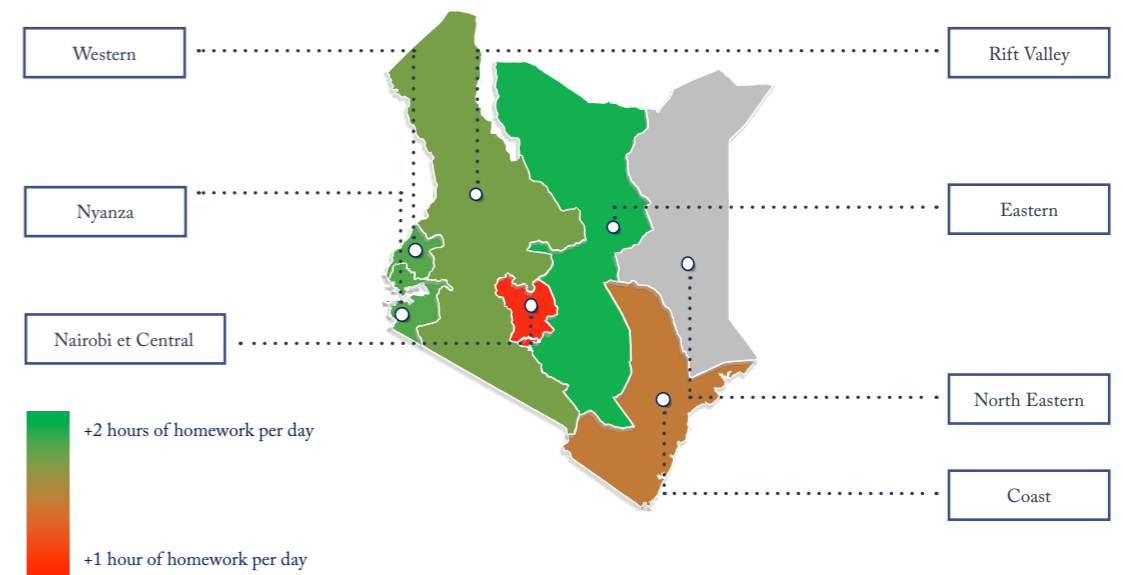


Figure 37: Impact by province - Additional homework time; N=1001

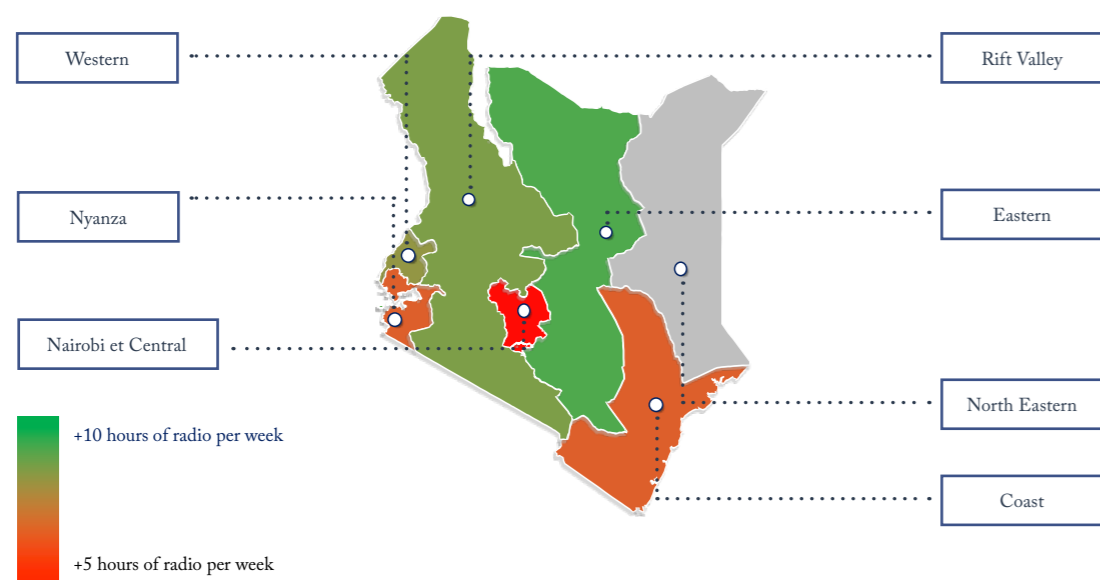


Figure 38: Impact by province - Additional radio time; N=1001

COUNTY AND PROVINCE DATA^{101,102}

County	Province	Population 2018	GCP 2018	GCP per capita 2018
Baringo	Rift Valley	666,763	92,866	139,278.87
Bomet	Rift Valley	875,689	159,569	182,221.09
Bungoma	Western	1,670,570	183,509	109,848.14
Busia	Western	893,681	86,712	97,027.91
Elgeyo Marakwet	Rift Valley	454,480	159,531	351,018.75
Embu	Eastern	608,599	103,734	170,447.21
Garissa	North Eastern	841,353	39,394	46,822.20
Homa Bay	Nyanza	1,131,950	114,198	100,886.08
Isiolo	Eastern	268,002	15,850	59,141.35
Kajiado	Rift Valley	1,117,840	107,805	96,440.46
Kakamega	Western	1,867,579	182,563	97,753.83
Kericho	Rift Valley	901,777	136,799	151,699.37
Kiambu	Central	2,417,735	421,918	174,509.61
Kilifi	Coast	1,453,787	119,295	82,058.10
Kirinyaga	Central	610,411	100,836	165,193.62
Kisii	Nyanza	1,266,860	163,546	129,095.56
Kisumu	Nyanza	1,155,574	194,489	168,305.10
Kitui	Eastern	1,136,187	101,560	89,386.69
Kwale	Coast	866,820	86,278	99,533.93
Laikipia	Rift Valley	518,560	81,095	156,384.99

County	Province	Population 2018	GCP 2018	GCP per capita 2018
Lamu	Coast	143,920	32,386	225,027.79
Machakos	Eastern	1,421,932	232,860	163,763.11
Makueni	Eastern	987,653	100,924	102,185.69
Mandera	North Eastern	867,457	35,101	40,464.25
Marsabit	Eastern	459,785	34,073	74,106.38
Meru	Eastern	1,545,714	229,646	148,569.53
Migori	Nyanza	1,116,436	96,337	86,289.76
Mombasa	Coast	1,208,333	332,122	274,859.66
Muranga	Central	1,056,640	173,018	163,743.56
Nairobi	Nairobi	4,397,073	1,492,323	339,390.09
Nakuru	Rift Valley	2,162,202	517,462	239,321.77
Nandi	Rift Valley	885,711	119,691	135,135.50
Narok	Rift Valley	1,157,873	179,226	154,789.00
Nyamira	Nyanza	605,576	103,239	170,480.67
Nyandarua	Central	638,289	245,203	384,156.71
Nyeri	Central	759,164	174,961	230,465.35
Samburu	Rift Valley	310,327	26,503	85,403.46
Siaya	Nyanza	993,183	95,265	95,918.88
Taita Taveta	Coast	340,671	51,381	150,822.93
Tana River	Coast	315,943	33,498	106,025.45
Tharaka Nithi	Eastern	393,177	67,692	172,166.73
Trans Nzoia	Rift Valley	990,341	116,683	117,821.03
Turkana	Rift Valley	926,976	78,301	84,469.29
Uasin Gishu	Rift Valley	1,163,186	162,273	139,507.35
Vihiga	Western	590,013	59,050	100,082.54
Wajir	North Eastern	781,263	37,159	47,562.73
West Pokot	Rift Valley	621,241	46,785	75,308.94

¹⁰¹ Kenyan Bureau of Statistics. (2019). *Gross County Product*.

¹⁰² Kenyan Bureau of Statistics. (2019). *Kenyan Population and Housing Census*. The population information disclosed in the Gross County Product report is not aligned with other sources, and therefore we stick to the census for population data.

