Scaling up off-grid solar energy access through improved understanding of customers' needs, aspirations and energy use of decentralised (SMART) Solar Home Systems – a case study of BBOXX customers in Rwanda.

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Abstract

In the fast-growing market of decentralised energy systems, stand-alone PV Solar Home Systems (SHSs) are among modern solutions which have quickly grown in numbers across the unelectrified parts of the world, substituting often polluting, expensive and inefficient sources like candles, kerosene or battery-powered torches used for lighting homes and businesses. Little research has been done to understand behavioural aspects of energy use among SHSs adopters. This case study aims to address this gap in the body of knowledge regarding energy use behaviour, needs and aspirations, focusing on SHSs users in Rwanda through both qualitative and quantitative research methods. It applies the Three-Dimensional Energy Profile framework to explore the needs, aspirations and energy use at a household level, with a recognition of differences among genders, different poverty groups and various system packages consisting of a diverse range of appliances. Time factor is considered to better understand whether and how needs and energy consumption change over time, demonstrating that energy use is dynamic and power consumption does not increase in a linear manner. Further findings reveal a substantial decrease in the use of candles, kerosene and batteries for lighting, with continued fuel stacking practices post-SHS adoption. Business applications are basic, as are the needs in terms of the most-desired appliances, which cover lighting, phone charging, access to information and entertainment, and other daily use appliances, such as shavers and irons. Aspirational level of access to energy services has the potential to be met by SHSs with increased availability and affordability of super energy efficient appliances, and appropriate business models. This can enhance the already significant impact on HHs, which has a well-defined gender dimension, with women benefiting the most. Policy and regulatory frameworks remain an important factor in scaling up off-grid energy access as key market enablers, channels of awareness-raising and trust-building among off-grid communities.

Impact Statement

This research has contributed to the existing body of knowledge on an emerging and highly important subject of current and future electrification efforts in Rwanda, which can be applied in other countries aiming to scale up their energy access rates and reach universal electrification by the 2030 deadline set by the Sustainable Development Goal 7. It has made a significant contribution to the academic body of research on the use and impact of decentralised energy solutions (DREs), such as off-grid Solar Home Systems, in a low-income country context, and by doing so improved the understanding of how such solutions are used by predominantly rural households in Rwanda.

This case study has informed the private sector of decentralised off-grid solar energy, offering valuable findings which can guide product and service design, and improve the provision of energy services in Rwanda, East Africa and beyond, now and in the future. It has had a direct impact on the industry partner (BBOXX), generating insights on the customer base which are critical for business model development, as well as continued product and service improvement. It has additionally helped in establishing a customer research department and the setting up of end-user focussed research activities which have since been expanded and have become an integral part of company's operations in Rwanda and other countries where BBOXX have their presence. Furthermore, the scope of and findings from this research have informed the design of the 'Socio-Economic Impact Research' and the off-grid solar impact metrics led by the Global Off-Grid Lighting Association (GOGLA) in partnership with a number of private companies in the off-grid solar sector, including BBOXX.

Impact on energy policy and regulation has been achieved in a twofold manner: first, through the seminar organised at and with the University of Rwanda College of Science and Technology (UR-CST) on "Off-grid solar in Rwanda: The way forward" (October 2016) where early findings of this research were presented and which was attended by various stakeholders from academia, the private and the public sectors, as well as the donor and NGO community in Rwanda; and second: through the *WIREs Energy and Environment* publication (2018) covering issues around existing policy frameworks and home-grown solutions (HGS), and their potential of scaling up energy access efforts by promoting off-grid solar solutions at the grassroots level.

Further impact on the wider energy sector, including both policymakers and practitioners, has been made through other published articles in renowned journals, including *Energy Policy* and *Energy Research & Social Science*, focusing on the application of Internet of Things (IoT) solutions as enablers of off-grid energy services (2017), and proposing a novel approach to understanding energy use behaviour of SSHSs adopters through Social Practice Theory (SPT) lens and the energy ladder framework (2018).

Having assumed an original approach to qualitative research methods on energy access, which, in addition to more traditional tools such as Focus Groups and surveys, has incorporated participatory photography to explore the rich and often unquantifiable aspects of energy uses and impacts, this research has contributed to the relatively small existing body of academic work which relies on photography as a tool for data collection.

Moreover, this research has impacted the public through several public engagement activities, including the mentioned seminar on off-grid solar energy in Rwanda, and photography exhibitions in both Rwanda (Kigali) (May 2017) and the United Kingdom (London) (June 2017) based on the participatory photography workshops with the users of SSHSs across Rwanda utilised as a data collection tool. Additionally, participants of the participatory photography workshops were able to share their experience and talk about why energy access matters in their lives and learn about the experience of other rural HHs across the country, which they would not be able to learn without this engagement. Feedback received from the participants strongly indicated that a positive impact had been achieved.

Through the researcher's collaboration with the Energy and Development Group at UCL, this research has been used as a case study and findings have been cited in the Group's publications, of which the researcher is also a co-author. Contacts established in the course of conducting this research in Rwanda have also been helpful in writing funding proposals, both for internal UCL opportunities and external ones.

Last but not least, this work has been presented at several conferences attended by the researcher, namely the Annual Association of American Geographers conference (San Francisco, March-April 2016), UNESCO Chair in Technologies for Development 'Tech4Dev Conference' hosted by the Cooperation & Development Centre (CODEV) and the École Polytechnique Fédérale de Lausanne (EPFL) (Lausanne, May 2016), 3rd UCL Urban Sustainability and Resilience Centre (USAR) conference (London, June 2017), Low Carbon Energy for Development Network (LCEDN) 6th conference (Durham, September 2017), and the 'Off-grid solar in Rwanda: The way forward' seminar (Kigali, October 2016) and 'Social Research on Off-Grid Solar' conference (London, December 2015) organised by the researcher. Further dissemination of this work has been done through blogs, hosted blogs, a personal website of the researcher, and interviews (UCL Civil, Environmental and Geomatic Engineering 'Keep it Civil' podcast, Rwanda TV of Rwanda Broadcasting Agency (RTV RBA)).

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Publications and Conferences

Lead Author:

Bisaga, I., Puźniak-Holford, N., Grealish, A., Baker-Brian, C., and Parikh, P. (2017). Scalable Off-Grid Energy Services Enabled by IoT: A Case Study of BBOXX Rwanda. *Energy Policy* 109(2017), pp. 199-207.

Bisaga, I., Parikh, P., Mulugetta, Y., and Hailu, Y. (2018). The potential of performance targets (*imihigo*) as drivers of energy planning and extending access to off-grid energy in rural Rwanda. *WIREs Energy Envir;* e310.

Bisaga, I. and Parikh, P. (2018). To climb or not to climb? Investigating energy use behaviour among Sola Home System adopters through energy ladder and social practice lens. *Energy Research & Social Science*, 44(2018), 293-303.

Co-Author:

Fuso Nerini, F., Tomei, J., To, L.S., Bisaga, I., Parikh, P., Black, M., Borrion, A., Spataru, C., Castán Broto, V., Anandarajah, G., Milligan, B., and Mulugetta, Y. (2017). Mapping synergies and trade-offs between energy and the Sustainable Development Goals. *Nature Energy* 3, 10-15 (2018). DOI: 10.1038/s41560-017-0036-5

Castán Broto, V., Stevens, L., Ackom, E., Tomei, J., Parikh, P., Bisaga, I., To, L.S., Kirshner, J., and Mulugetta, Y. (2017). A research agenda for a people-centred approach to energy access in the urbanizing global south. *Nature Energy*, PersPective. DOI: 10.1038/s41560-017-0007-x

Conferences presented at:

CEGE Research Festival, London (UCL), 10 November 2015.
Work presented: Scaling up the solar energy revolution in Africa through improved remote monitoring and customer satisfaction of decentralised systems.

UCL and University of Edinburgh 'Social Research on Off-Grid Solar', London, 9-10 December 2015. Session theme: User interaction and experience.
Work presented: After-sales services: the role of human-centred design.

Association of American Geographers (AAG) Annual Meeting 2016, San Francisco, 29 March – 2 April 2016. Session theme: Energy in the SDGs: Understanding Sustainable Energy Solutions in the Global South.

Work presented: Scaling up the solar energy revolution in Africa through improved remote monitoring and customer satisfaction of decentralised SMART Solar Home Systems.

UNESCO Chair in Technologies for Development 'Tech4Dev Conference' hosted by the Cooperation & Development Centre (CODEV) and the École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, 2-4 May 2016. Theme: From Innovation to Social Impact.
Work presented: BBOXX SMART Solar: A Case for Scalable Off-Grid Energy Services Enabled by IoT.

3rd International Conference on Urban Sustainability and Resilience, London, 13-14 June 2017. Theme: Resilient and green infrastructure.
Poster presented: Solar Home Systems (SHSs) as viable, clean energy access options for off-grid and 'under the grid' populations: a case study of Rwanda.

Low Carbon Energy for Development Network 6th Conference**,** Durham, 11 & 12 September 2017**.** Theme: Equity and Energy Justice.
Work presented: Fuso Nerini et al. (2017) & 'Through the Lens' Photography Exhibition.

Statement of Originality

I, Iwona Bisaga, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis with the use of citations and references. All cited quotes of the interviewed study participants have also been marked accordingly.

I also confirm that I have fully acknowledged by name all individuals and organisations that have contributed to this research with their time and shared insights. I further declare that this thesis has not been accepted in part or in full for any other degree, nor will it be submitted for any other degree.

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Last but not least, I want to thank my family for not only supporting and encouraging me from very early on, but also for making me who I am and giving me the strength to always go above and beyond: Thank You.

List of Acronyms and Abbreviations

AfDB – African Development Bank

BB SL – BB Super Lights

BERA – British Educational Research Association

BNEF – Bloomberg New Energy Finance

BTC – Belgian Technical Cooperation (Belgian Development Agency)

CGAP – Consultative Group to Assist the Poor

CIF – Climate Investment Funds

COMESA – Common Market for Eastern and Southern Africa

CSCC – Customer Service Call Centre (BBOXX)

DRE – Decentralised Renewable Energy

EAC – East African Community

EARP – Electricity Access Roll-Out Program (Rwanda)

EDCL – Energy Development Corporation Limited (Rwanda)

EPD – Energy Private Developers (Rwanda)

EPFL – École Polytechnique Fédérale de Lausanne

ESF – Energy Service Fee

ESMAP – Energy Sector Management Assistance Program (of the World Bank and the International Finance Corporation)

EUCL – Energy Utilities Corporation Limited (Rwanda)

FG – Focus Group

FONERWA – National Climate and Environment Fund (Rwanda)

FT – Field Trip

DfID – Department for International Development (of the United Kingdom)

GIZ – Deutsche Gesellschaft für Internationale Zusammenarbeit (formerly GTZ: Deutsche Gesellschaft für Technische Zusammenarbeit) (the German International Development Department)

GLE – Great Lakes Energy

GOGLA – Global Off-Grid Lighting Association

GoR – Government of Rwanda

HLP – high likelihood of being poor

IEA – International Energy Agency

IFC – International Finance Corporation

ILP – intermediate likelihood of being poor

IoT – Internet of Things

IPA – Innovation for Poverty Action

IRENA – International Renewable Energy Agency

LCEDN – Low Carbon Energy for Development Network

LFS – Labour Force Survey (by the Government of Rwanda)

LLP – low likelihood of being poor

LPG – liquefied petroleum gas

M2M – Machine to Machine

MDGs – Millennium Development Goals

MININFRA – Ministry of Infrastructure (Rwanda)

MTF – Multi-Tier Framework (developed by the World Bank)

NISR – National Institute of Statistics of Rwanda

NW – North-West

ODI – Overseas Development Institute

PAYG – Pay as You Go

Pico-PV – term typically used to describe a solar photo-voltaic lantern, the smallest kind of a solar PV system

PPP – purchase power parity

PPW – Participatory Photography Workshop

PV – Photo-voltaic

RA – Research Assistant

RDB – Rwanda Development Board

REG – Rwanda Energy Group

RURA – Rwanda Utilities Regulatory Authority

SACCO – Savings and Credit Cooperative Organisation

SDGs – Sustainable Development Goals

SE4All – Sustainable Energy for All (United Nations' initiative)

SHS – Solar Home System

SREP – Scaling up Renewable Energy Programme

SSHS – SMART Solar Home System

SSA – Sub-Saharan Africa

SPT – Social Practice Theory

UNEP – United Nations Environment Programme

UR-CST – University of Rwanda College of Science and Technology

USAR – Urban Sustainability and Resilience Centre

WB – World Bank

WBREDA – West Bengal Renewable Energy Development Agency

WHO – World Health Organisation

Note on Currency

Rwanda francs (RWF), which is the national currency in Rwanda, is used and referred to throughout this thesis. Conversion rates for RWF are as follows:

RWF 100 = USD 0.12

RWF 100 = GBP 0.088

RWF 1000 = USD 1.2

RWF 1000 = GBP 0.88

Exchange rates used above are from July 16th, 2018 as stated by the official currency exchange of the Bank of Kigali (in Rwanda).

To the millions of women, men and children around the world
who live their daily lives without access to clean, modern energy sources.

Chapter 1 Introduction

1.1 Problem statement

Modern, clean energy services are essential for countries' socio-economic development and for human well-being. They are also necessary for the provision of other services, including water and sanitation, healthcare, mechanical power, agriculture, education and telecommunications (Fuso Nerini et al., 2017). However, despite the important role energy plays in ensuring everyday basic needs are met, approximately 1.1 billion people (or 17% of global population) currently live without access to electricity and further 2.7 billion lack improved cooking facilities (World Energy Council, 2017). Sub-Saharan Africa (SSA) and Asia are home to over 95% of those with no access to electricity, with majority of them living in rural areas. The International Energy Agency (IEA) (2016) estimates that progress in urban electrification since 2000 has been twice as fast as that in rural areas, with SSA becoming the least electrified region worldwide in terms of the total number of energy poor and the proportion of its total population. The IEA (2017) also estimates current electrification rate in SSA at 43%, with the progress towards achieving universal energy access by 2030 uneven across the countries.

The urgency of the situation has contributed to increased efforts in addressing the energy poverty challenge in the last few years. The recent Sustainable Development Goals (SDGs) for 2015-2030 now include a separate goal for energy, a change from the Millennium Development Goals (MDGs) in which energy access was not recognised as one of the key strategic development points. The UN Decade of Sustainable Energy for All (SE4All) initiative was launched in 2014, and the IFC and World Bank Lighting Africa Program has been running since 2007. With multiple emerging frameworks and initiatives, reaching universal access has become one of the top priorities for ensuring sustainable development. The role of decentralised energy solutions in reaching universal access has gained recognition both from the private and public sectors, offering a more cost- and time-effective option than extending grid connections for providing access to remote rural populations where demand and the ability to pay tend to be lower (IRENA, 2018; GOGLA, 2017; Hirmer & Cruickshank, 2014; Batchelor et al., 2014; Bhattacharyya, 2013).

In the fast growing market of decentralised energy systems, stand-alone PV Solar Home Systems[1] (SHSs) and solar lamps (which are collectively called Off-Grid Solar devices (Dalberg Advisors & Lighting Global, 2018)), as well as solar PV mini-grids are among modern solutions which have quickly grown in numbers across the developing world, substituting expensive and inefficient sources like candles, kerosene or battery-powered torches used to light up homes and businesses (Bensch et al., 2017; Scott & Miller, 2016; Chaurey et al., 2012; Lighting Africa, 2011). These non-renewable sources can cost African families as much as $70 – 110 USD per year and it is estimated that on average low-income Africans spend between $13.2 – 17.3 billion USD on these fuels annually (World Bank et al., 2017). Due to a sharp fall in PV technology prices (up to 50% in the last 10 years, as a result of higher panel and battery efficiency, as well as super energy-efficient appliances) which are expected to fall another 45% by 2020 (Lighting Global & Bloomberg New Energy Finance (BNEF), 2016), the modular nature of PV systems and the proliferation of innovative Pay as You Go (PAYG) solar providers, solar energy has become an attractive and affordable option for rural populations (Schutzeichel, 2016; Halder & Parvez, 2015; Friebe et al., 2013; Chaurey & Kandpal, 2010). Solar lanterns can costs as little as $20 (SolarAid, 2015) and SHSs prices range from approx. $120 – $400 USD per unit (depending on the size, capacity, number of appliances etc.). Figure 1.1 shows the change of SHS prices over time between 2009 and 2014. Steep fall can be observed between those years and between standard versus energy-efficient appliances.

[1] Renewable Energy Policy Network for the 21st Century (REN21, 2017: 100) define SHSs as systems "(10-500W) [which] generally consist of a solar module and a battery, along with a charge control device, so that direct current (DC) power is available during dark and cloudy periods. SHSs provide electricity to off-grid households for lighting, radios, television, refrigeration and access to the internet."

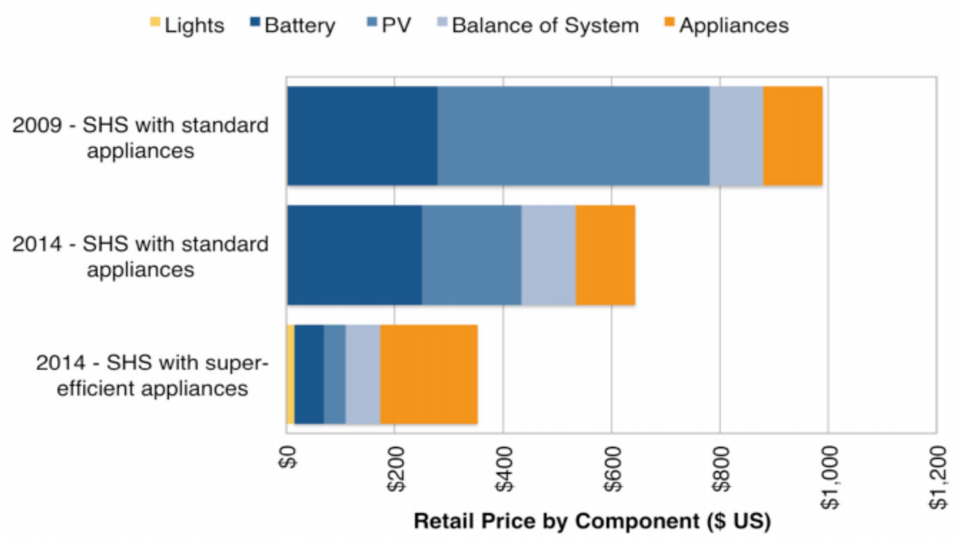


Figure 1.1. Retail purchase price change for SHSs over time and with factoring in energy-efficient appliances. Source: Scott & Miller (2016: 13).

The Global Off-Grid Lighting Association (GOGLA) estimate that they were providing improved energy access to nearly 360 million people globally in 2017, with a further potential of serving another nearly 2.2 billion people (with no or unreliable grid access) (Dalberg Advisors & Lighting Global, 2018).

However, despite the benefits offered by decentralised PV systems, there has been a growing concern about the level of energy access they can provide to low and low- to middle-income off-grid households (Bazilian et al., 2012). Bazilian & Pielke (2013) contend that delivering energy services for poverty reduction and sustainable development means more than just delivering energy to households. Instead, it entails delivering adequate and reliable energy services that meet individual and household-level needs and aspirations, which are not static but rather changing over time (World Bank, 2013). Providing lights might be enough to eliminate darkness and extend productive and study hours into the evening, but not enough to support more energy intensive, often income-generating activities. It has been argued that the latter is what SHSs and solar lamps may not be capable of doing (Jacobson, 2004). Understanding the actual demand and use of energy among off-grid households would be an invaluable insight that could boost electrification efforts going forward. As stated by the World Bank's Energy Sector Management Assistance Program (ESMAP) in the Annual Report (2015: 30): "Tracking how people are using energy and for what purposes can inform investments in energy projects to strengthen the overall energy delivery system from physical infrastructure to policy and regulation."

1.2 Research partner

In this crucial time of planning for and executing on the 2030 SDG Agenda, the role of the private sector and private providers of decentralised systems has been increasing and gaining importance (Alstone et al., 2015; Deloitte & Touche, 2015). There has been a growing number of SHSs providers across the developing world offering PAYG off-grid solar solutions and BBOXX, the partner company of this research, is one of them. BBOXX design, manufacture and distribute remotely monitored SHSs in a number of countries across Sub-Saharan Africa and Asia. Their key operations are located in Rwanda (with the East African headquarters in Kigali) and in Kenya. For an example of a standard SHS as provided by BBOXX, please see Appendix 1. Similar systems are offered by providers such as M-Kopa (highest number of products sold in Kenya), Mobisol (Tanzania and Rwanda), d.light (Kenya), Off-grid Electric (Tanzania and Rwanda), and others. BBOXX and other providers have benefitted greatly from the recognition of PAYG SHSs by financial investors and have received a considerable proportion of the overall financing seen in the sector in 2016 (see Figure 1.2), with the total investment reaching $223 million, up by over 40% from 2015.

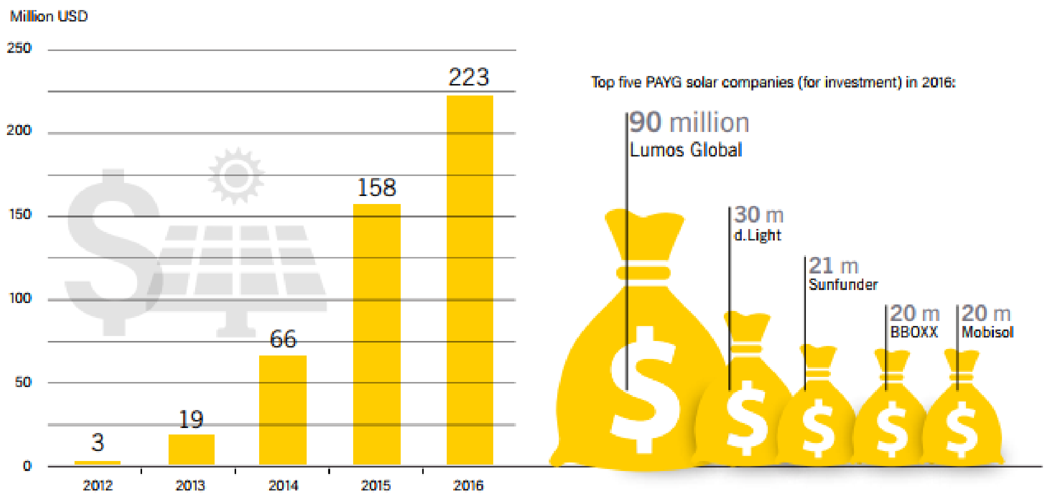


Figure 1.2. Investment in PAYG Solar Companies, 2012-2016. Source: adopted from REN21, Renewables 2017 Global Status Report (2017: 106).

The growing support of development institutions has also meant increased resources for the sector. More than 25 countries (predominantly in SSA) have partnered with the World Bank Group to build capacity and channel more funding to the sector, thus boosting the potential of reaching the over 600 million people in the region without any or without reliable access to electricity (Dalberg Advisors & Lighting Global, 2018).

Innovation in the PV technology and business models (including PAYG solutions) have been some of the key drivers in the sector and its increasing financial support. However, BBOXX's innovative take on SHSs is also shown in their in-house development of remote monitoring of the systems. BBOXX was founded in 2010. The initial business model was to wholesale SHSs to distributors around the world. By 2013 challenges with the scalability of such a model became apparent, putting at risk the company's plans to provide electricity to 20 million people by 2020, thus making a contribution to ensuring universal energy access globally. In East Africa, where the company decided to set its operations, limited financial capacity of households was the chief barrier to adoption, making it impossible to purchase an SHS outright. What was required to overcome it was financing of the systems and end-customers by enabling large scale institutional investment. The development of SMART Solar – a product and a platform on which a traditional financial product can be built, was a result of that pressing need. SMART Solar combines knowledge of off-grid SHSs and the latest developments in Internet of Things (IoT) and Machine to Machine (M2M) technologies. Allowing remote control of products, de-activation if customers delay their monthly payments, and detection of deliberate attempts to temper with the device, the platform reduces investors' risk. It is also used for proactive servicing of deployed systems. Various problems, including degraded batteries and dusty solar panels, can be inferred from the transmitted data. Information is then communicated to the customers through a network of repair technicians or a dedicated call centre. The technology is also used to gain a better understanding of off-grid solar energy (Bisaga et al., 2017). The incorporation of SMART Solar into SHSs has resulted in the creation of SMART Solar Home Systems (SSHSs), the use of which is the focus of this research.

The choice to focus on customers of one of the operating providers in Rwanda, rather than multiple ones[2], was dictated by the ability of the researcher to access all real-time end-user data, which is a unique feature of the systems currently offered by as few as a couple of SHS providers in this domain. Through a collaboration with BBOXX (also referred to as 'the provider' throughout this thesis), access to conduct further data collection was also enabled. Although it poses a limitation[3] to the study as products and services of only one provider are investigated, it has allowed for a novel research opportunity combining various data sets, including usage data which is otherwise difficult to obtain for reasons of ethics and confidentiality. The study also encompasses a range of system types (packages) which cover the most common SHSs and their average capacity across the whole market, therefore the researcher believes that the sample can be considered representative of an average experience of a SHS user in Rwanda. A breakdown of different system types for survey 2 (S2) and survey 3 (S3) can be seen in Table 5.3 in section 5.1.3 and for participatory photography workshops (PPW) participants in Table 3.7 in section 3.1.4.

1.3 Research location

Rwanda has been selected as a country of focus for this study as it is one of BBOXX's key markets and it is also one of the fastest growing off-grid solar markets in the region (Scott & Miller, 2016). As opposed to Kenya, which has a well-established presence of solar PV and has been the subject of investigation of numerous studies (e.g. Muok et al. 2015; Mutua & Kimuyu 2015; Ulsrud et al. 2015; Da Silva et al. 2014; Lay et al. 2013; Rolffs et al. 2014; Jacobson 2004), Rwanda is in earlier stages of solar PV development. It presents a huge market potential, yet research on users of SHSs has been more limited, with additional investigations carrying greater value for the development of the sector than in more mature markets. Additionally, the number and range of customers BBOXX had in Rwanda in 2015/2016 allowed for an investigation of the time-dimension of energy use through SSHSs as by early 2016 there was a

[2] There are numerous SHSs providers in Rwanda, with approximately 4-5 key players. One of them is the provider whose customers this research focuses on.
[3] Study limitations are further discussed in section 7.4.

sufficient number of adopters who had been using their systems for over one year, making the split into three time groups (Group 1: >1 year, Group 2: 6 months to 1 year, and Group 3: <6 months, discussed in section 3.1.4) possible.

Figure 1.3. Map of Rwanda. Source: OnTheWorldMap (2018) at http://ontheworldmap.com/rwanda/rwanda-political-map.html.

Rwanda has a population of 11.9 million and a population density of 460 people/km2 (one of the highest in Africa), with approximately 52% of the whole population being women (National Institute of Statistics (NISR), 2016). Agriculture, forestry and the fishery sector employ the highest number of both women (over 66%) and men (43%) of 16 years and above (ibid.). Approximately 45% of Rwandans live below the poverty line and have low average spending of $1.65 per week per person (WB, 2015). In 2012, its electrification rate was 17%, with considerably higher rates in urban than rural areas (67% urban vs 5% rural) (Baringanire et al., 2014). There has been, however, a strong focus on energy access, which is recognised as a critical factor in achieving sustainable growth and development. It was demonstrated in Rwandan Government's commitment to reach 48% access to grid electricity by June 2018 and provide off-grid solutions to 22% of the population (MININFRA, 2016)[4]. The access rate as of early

[4] This strategy has since been revised. In 2017, the GoR revised the energy strategy and developed the 7-5-2 plan which aims to deliver power to the entire city of Kigali in the next two years, all productive users by 2022 and all households by 2024, with 48% of these connections being supplied by off-grid solutions. 100% electrification is therefore now set to be achieved by 2024.

2018, according to the Rwanda Development Board (RDB) (2018), stands at 40.5% (with on-grid representing 29.5% and off-grid access making up 11%).

The Government of Rwanda (GoR) has shown clear and strong support for the off-grid solar sector by including it in its Economic Development and Poverty Reduction Strategy II (GoR, 2013). Disch & Bronckaers (2012) estimate that a potential market of one million households requiring lighting and mobile phone charging until 2020, and likely beyond, exists in Rwanda. With an annual GDP growth of 8% annually in the last decade and poverty rates decreasing steadily, an increasing number of people are able to afford to pay for electricity, with the often attractive option of off-grid solutions if the Government cannot economically provide them with a grid connection (Baringanire et al., 2014). Private sector investment, improved governance and regulatory capacity of the GoR have ranked the country as number 32 out of 189 on the IFC/WB ease-of-doing-business index (down from number 139 in 2005) (ibid.) and as number 1 in the East African Community (EAC) region. Historically, despite an overall favourable regulatory and investment environment conditions, the Rwandan off-grid sector has been largely directed by donor agencies and government projects rather than through engaging with the private sector to address practical opportunities and challenges. However, in 2015 the Rwanda Utilities Regulatory Authority (RURA) released the off-grid simplified licensing regulation and in the last couple of years partnered with over 20 companies supplying SHSs (both through Government programmes and independently). The main providers of such systems include BBOXX, Mobisol, Ignite Power, and Off-Grid Electric (now Zola Electric). According to RDB (2018), by the end of 2017, approximately 190,000 SHSs had been installed across the country by private providers driving the market of off-grid solar systems, supplying electricity to nearly 1.2 million households (a dramatic rise from practically 0% some 5 years ago to upwards of 11% at the end of 2017).

Better involvement and coordination of all stakeholders, including the private sector, have been advised as a trigger for a faster acceleration of the off-grid market (Diecker et al., 2016). SHSs, as was predicted by Kirai et al. (2009) on behalf of GIZ (formerly GTZ), have been an important sector for the growth of solar PV (Scott & Miller, 2016). Lighting Global and Bloomberg New Energy Finance (BNEF) (2016) estimate that a stronger partnership between private sector players, such as off-grid start-ups, retailers and appliance manufacturers (marked as 'More corporates' in Figure 1.4 below) has the potential to drive a faster acceleration of solar PV adoption (including SHSs and pico-solar) across Sub-Saharan Africa by 2020 than if there is focus on more policy only (Figure 1.4).

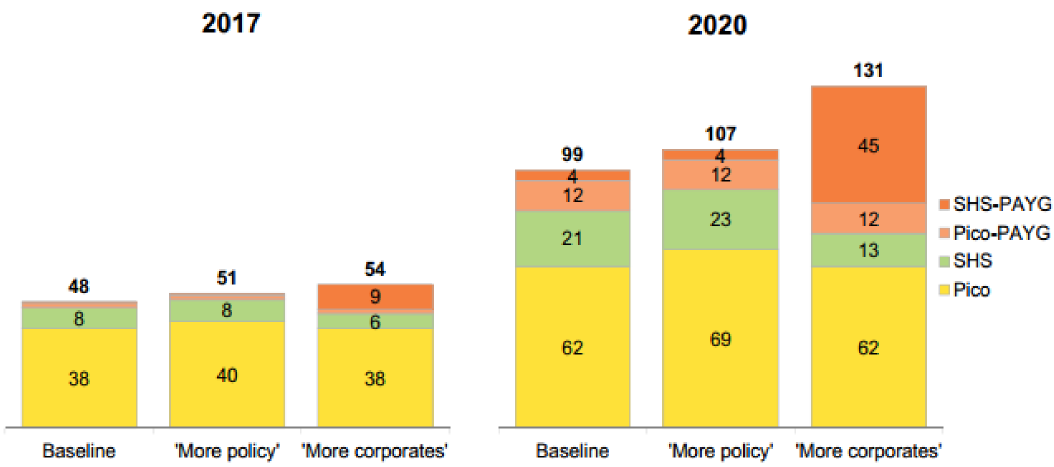


Figure 1.4. Growth scenario comparison. Forecast for off-grid solar users (millions of households). Source: adopted from Lighting Global and Bloomberg New Energy Finance (2016: 81).

Especially the PAYG SHSs are favoured in this scenario- a model which has been growing rapidly in the past years and has quickly become popular among off-grid customers (Lighting Global and BNEF, 2016; see more in section 2.4 on business models). Given these predictions, the ambitious electrification plans in Rwanda, and the favourable economic and investment environments, companies such as BBOXX can help contribute to achieving these targets and provide millions of people currently living off the grid with lighting, mobile phone charging, access to information and the use of other household appliances. Such private sector assistance will not only ensure faster achievement of the 100% electrification target but will also help increase the proportion of renewable energy in the overall energy mix in the country, in line with SDG7, and bring about social and economic impacts, thus contributing to the achievement of numerous other SDGs.

1.4 Research scope

Since its inception in May 2015, the study has shifted its scope as a result of the findings from the first survey conducted with 126 users of SSHSs in Rwanda, and the review of existing literature. The initial objective was to explore the impact of remote monitoring on customer satisfaction with SHSs, testing the question whether or not customers with SSHSs are more satisfied with their systems than those without the remote monitoring component. This goal soon became impossible to achieve as BBOXX rolled out remotely monitored systems across all their customers in the second half of 2015, leaving no control group (with non-monitored systems) to work with. The focus then moved to investigating energy use behaviour of SSHSs users, as well as their needs and aspirations and satisfaction with off-grid solar energy.

1.5 Research questions

There has been little research done so far to understand the behavioural aspects of energy among SHSs users, and no study has been conducted on users of remotely monitored SHSs. This research aims to address the existing gap in the body of knowledge regarding the behavioural aspects of energy use and the understanding of users' needs and aspirations that has been identified in the process of conducting literature review, particularly in the case of decentralised energy systems such as SHSs (Groh et al., 2016; Bellanca & Garside, 2013; Bhattacharyya, 2012; Kowsari & Zerriffi, 2011; Gustavsson, 2007) and SMART SHSs on which this study will focus. The survey findings have further shaped the scope of the study. The innovative SMART Solar technology which allows for remote monitoring of the systems offers the opportunity to track the daily amounts of energy consumed. Combined with customer profiling on energy uses, needs and aspirations, the measuring of their satisfaction with SSHSs and through the application of the three-dimensional energy profile framework together with the social practice theory (section 2.9) , this research sets to answer the following questions:

1. How is energy accessed and used in the household, pre and post adoption of a SSHS?
2. What is end-users' energy behaviour and consumption as tracked by SSHSs and as self-reported? Does it increase over time? And does it depend on the system type[5] (i.e. the set of available appliances)?

[5] System types here means the packages customers purchased which vary on the accompanying appliances but not the system size (all systems are 50W, 12V 17Ah).

3. What are the energy needs and aspirations? Do they differ among end-users? And are they met by SSHSs?
4. What are the key socio-economic impacts as experienced by the users of SSHSs?

And finally

5. How can improved understanding of energy use and customers' needs and aspirations, as well as key impact points, help provide adequate energy services and scale up off-grid solar energy access, in Rwanda and beyond?

By exploring the above questions, which have been subject to continuous revision in the course of the project, this research has attempted to provide a better understanding of the ways in which users of SHSs utilise energy in the household (the micro level of understanding) and learn about their needs and aspirations. Assuming the three-dimensional energy profile framework proposed by Kowsari & Zerriffi (2011) as the framework for analysis (further explained in section 2.9), it has moved away from the dominant emphasis on economic variables, such as income and expenditure, in analysing household energy use patterns and demands. Instead, it has adopted a more comprehensive approach to understanding household energy use as a complex interaction between economic, technical, social, cultural and physical (or the physical environment) variables (Masera et al., 2000), in order to inform stakeholders responsible for propelling further growth of SHSs and similar solutions in a tailored manner which can meet the growing energy needs across off-grid communities.

1.6 Thesis outline

This thesis comprises of 7 chapters. Chapter 1 laid out the background, the context of the study and presented the problem statement. The remaining 6 chapters are as follows:

Chapter 2 provides an overview of literature on the subject, covering the place of SHSs in the development agenda and the role they play in achieving SDG7 (section 2.1); challenges faced by SHSs in places where they have been deployed to date (section 2.2); the energy access debate and the position of SHSs (section 2.3); various existing business models of SHSs providers (section 2.4); energy use behaviour among SHSs adopters (section 2.5); energy needs and aspirations debate (section 2.6); users' satisfaction with SHSs (section 2.7); and the existing literature on remote monitoring of decentralised systems (section 2.8).

Chapter 3 outlines research methods and methodology applied in this research (section 3.1) and details on field work conducted in the course of this research in several intervals (June-September 2016, November 2016, March-April 2017, and October 2017) (section 3.1.3); data collection and the schedule of data collection activities (sections 3.1.1 and 3.1.2); sampling (section 3.1.4); and ethical considerations this research required from its conception to completion (section 3.4).

Using the analytical framework and its components, Chapter 4 explores the contextual domain of energy use in households where SSHSs have been adopted. It presents the external conditions which contain the energy policy and regulatory frameworks in Rwanda (section 4.1), followed by household characteristics (section 4.2), and energy use among households adopting SSHSs (section 4.3), including prior to system adoption (section 4.3.1). Section 4.4 offers chapter summary and a brief discussion.

Chapter 5 covers the personal domain of energy use. It examines habits and experience of energy use (section 5.1), attitudes towards and satisfaction with off-grid solar energy systems (section 5.2), needs and aspirations related to energy access (section 5.3), and impact of getting access to modern energy (section 5.4). Section 5.5 offers chapter summary and a brief discussion.

Chapter 6 contains a discussion of findings and Chapter 7 presents conclusions, including key findings and contributions (section 7.1), implications for different stakeholders (section 7.2), further research recommendations (section 7.3) and study limitations (section 7.4).

Chapter 2 Literature review

2.1 Solar Home Systems in the development agenda

Solar energy, including SHSs, has proven to be one of the most economically feasible and easiest options to expand energy access in the Global South (IEA, 2017b). They have enjoyed sustained growth over the last few years, with installations rising from 1.2 million to over 6 million between 2002 and 2015 (IRENA, 2015), and continuing to scale rapidly. The Off-Grid Solar Market Trends Report 2018 (Dalberg Advisors & Lighting Global, 2018) estimated that SHSs sales reached over one million units in 2017 only, that number including both affiliate (quality assured, Lighting Global certified units) and non-affiliate (non-certified also called generic) sales. Through various financing and distribution models (including PAYG), SHSs have become accessible to those who have so far had to rely on other sources for energy, such as kerosene lamps, candles or torches running on pricy batteries (UNEP Finance Initiative, 2012). They have been adopted as part of a wider electrification strategy, particularly for remote, rural populations, by many governments around the world, notably in Kenya, Uganda, Tanzania, Ethiopia, Rwanda, India, Bangladesh, and more recently have spread to West Africa (Togo, Nigeria, Ghana, Senegal and the Ivory Coast being so far among the most committed) (WB, 2017). East Africa has been the leader in the market, taking up over 85% of it between 2013-2017 (of the combined markets of East Africa, West Africa and Asia) (Dalberg Advisors & Lighting Global, 2018).

Off-grid solutions (OGS) have been gaining increased attention in the academic community in the last decade as markets develop and mature, with a growing number of studies across different regions, and in particular East Africa and South-East Asia where those solutions have been supported by targeted electrification strategies and widely deployed (Lemaire, 2018). SHSs offer a number of socio-economic benefits to users, including reduction of household expenditure on inefficient lighting sources such as kerosene, wood or candles. For example, Buragohain (2012) found that in three Indian states households adopting solar products reduced expenditure on lighting by half. In the study of SHS users in Kenya, Zollmann et al. (2017) found that reduction of expenditure on energy sources among low-income households in the short-term was unlikely, especially if the SHS repayment time was constrained to one year only. Prior fuels (e.g. kerosene, candles, and batteries) used to be purchased as and when needed, or often households would go without any lighting at times other needs would come up or become more critical. They would spend, on average, $170 per year as opposed to $207-$244 per year on a SHS. However, longer term repayment options would bring the before and after expenditure to comparable levels and result in savings in the long run. Other advantages include savings on mobile phone charging and opportunities for setting up businesses or extending the time of income generating activities (Scott et al., 2017; Chakrabarty & Islam, 2011), as well as time savings resulting from the elimination of the need to travel (often walk) long distances to purchase lighting fuels or charge mobile phones (Perera et al., 2015). In an analysis of 98 documents related to the impact of pico-solar and SHSs applications, Lemaire (2018) found that such systems have a significant impact on the quality of life and the feeling of connectedness of the users through access to radios, TVs and the possibility to always have one's phone charged. Furthermore, the development of the value chain associated with solar energy services has created thousands of jobs and contributed to the formation of a new off-grid energy market, offering new funding streams flowing into the existing retail networks (GOGLA, 2017; Jacobson, 2007).

Other development impacts of SHSs include improved health due to the eradication of candle and kerosene smoke, and improved educational performance of children whose study hours extend into the evening time (SolarAid, 2015). Longer and more efficient lighting also means more time for families to socialise after dark, in a much safer environment free of fire hazards, often accompanied by a radio or a TV, which in addition to enabling users to feel connected to the world, also offer access to information and entertainment (Ulsrud et al., 2015; Alstone et al., 2015). Such access may be lacking in unelectrified homes and those with access limited to small solar lights only. The Global Off-Grid Lighting Association (GOGLA) have recently also included unreliable-grid population (as a distinct category) into the ranks of those having inconsistent and/or poor quality grid connection and therefore facing similar challenges to those of unelectrified households (Dalberg Advisors & Lighting Global, 2018). Affordable mobile phone charging, in addition to allowing for saving on charging fees, has made access to financial services possible to thus far unserved rural populations across the Global South (GOGLA, 2017; David et al., 2015; Urmee & Harries, 2011). Worrall & Scott (2018) have hailed decentralised OGS as transformative for the lives and well-being of HHs with no or unreliable energy access, enhancing education, health (and health care), productivity as well as women's empowerment and gender equality.

2.2 Challenges

Poor quality SHSs, sold upfront and without warranties have damaged the reputation of solar in many areas (Muok et al., 2015; Friebe et al., 2013). Users who encounter problems with their systems do not always have the necessary repair support included with their product and cannot afford to pay extra for it which often has a twofold effect: systems being disused (Lemaire, 2011) and users losing trust in the technology (Lighting Africa, 2013; Serpa & Zilles, 2007). This, in turn, can discourage those in their communities from purchasing similar systems in the future (Lighting Africa, 2013; Laufer & Schäfer, 2011). Proactive services which address these issues as and when they arise can prevent such negative consequences and at the same time enhance user experience and satisfaction. BBOXX, through the SMART Solar platform and its network of support technicians, work towards achieving this goal.

In Pakistan, lack information and trust in off-grid solar kits providers has been found to be one of the main obstacles to adoption (Abdullah et al., 2017). The relatively limited knowledge of the off-grid solar technology in areas where they have the potential to address the energy access challenge can prevent households from purchasing OGS, and particularly SHSs due to their higher costs and often long-term commitments (usually between 1 and 10 years, on average). In places with a higher number of both providers and adopters, the likelihood of off-grid households choosing OGS is higher as word of mouth and shared experiences of other households act as powerful encouragement tools and one of the best ways to popularise the technology (Scott, 2017; GIZ, 2016; Lay et al., 2013). Awareness of and access to (as in: availability of) OGS, along with affordability and advantage (mentioned in the previous section) are important factors steering households' decision making. They make up the 4As framework developed by Acumen and Bain & Company (Tam et al., 2014), first applied to the agricultural sector to depict key drivers for adoption of agricultural innovation, and later expanded to the energy sector, including off-grid solar (Harrison & Adams, 2017).

In addition to the lack of trust in off-grid solar providers, quality and servicing problems with SHSs, it has been argued that such small-scale solutions cannot meet the growing energy demands at their current capacity (typically 11 to 100Wp) and support energy-heavy productive uses (Azimoh et al., 2015; Brew-Hammond, 2010; Jacobson, 2007; Prasad, 2007). Aklin et al. (2017) have argued that SHSs benefit end-users by displacing kerosene, however, they have questioned if the wider socio-economic impacts are indeed observed based on the weak evidence found in four reviewed randomised controlled trials (RCTs) in South Asia and Africa. Lemaire (2018) argues that despite small solar systems being perceived as unable to have any meaningful impact due to limited capacity, evidence exists to support the opposite notion (i.e. significant impact), although any definitive quantitative impacts are difficult to draw at this point. Baurzhan & Jenkins (2016) have reviewed the feasibility of off-grid solar PV systems for rural electrification in SSA and, having considered cost-competitiveness, affordability, financing, environmental impact and poverty alleviation, concluded that OGS are not feasible both economically and financially for rural HHs in SSA unless subsidised from donor funds or foreign investors, as a result recommending electrification efforts be continued via local and national grid extensions. Leo et al. (2018) have conducted mobile phone surveys with nearly 30000 respondents divided into grid and non-grid users in 12 African countries. Their study suggests that neither grid nor off-grid energy services are adequate enough to meet many African consumers' energy needs, while at the same time finding that consumers see grid and off-grid as complementary solutions for energy access, rather than as competing ones, and that even among connected, urban customers there exists a market for OGS, such as SHSs and solar lanterns.

As contended by Wamukonya (2007), off-grid solar PV systems, with all their advantages and disadvantages, are not a panacea to the energy challenge and more questions need to be raised to understand the socio-cultural and economic priorities of rural households. This is of particular significance given the widely acknowledged energy stacking practices among not only low income, but also other layers of society in developing countries. Contrary to the idea of climbing the 'energy ladder', which assumes that both traditional and modern forms of energy are available and households will choose to switch to the next best source as soon as they can afford it, it has been shown that both rural and urban households follow more complex energy transition trajectories and tend to rely on more than one energy source as their income increases and improved solutions become available, a term that has been coined as 'energy stacking' (Figure 2.1) (Tait, 2017; van der Kroon et al., 2013; Kowsari & Zerriffi, 2011; Nansaior et al., 2011; Masera et al., 2000).

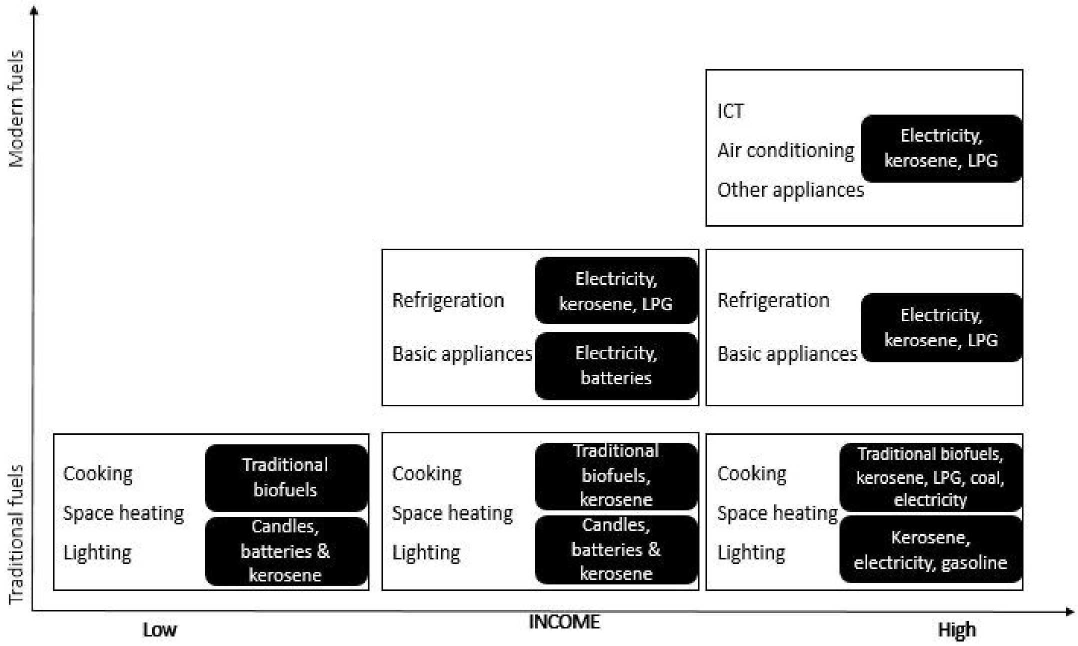


Figure 2.1. Energy stacking showing simultaneous use of different energy sources regardless of income levels. Source: adapted from Kowsari and Zerriffi, (2011: 7509).

As contended by Tait (2017), the use of multiple fuels is an important aspect of energy use which tends to be poorly captured. The continued use of traditional fuel sources (such as firewood, kerosene etc.) can heavily undermine the benefits brought to the households through clean energy solutions and ultimately the wider investment in those might not be yielding all the benefits it intends to. Understanding this issue, and the needs of households together with their behavioural drivers, is important to ensure energy transitions can bring about a holistic change for the better, eliminating persisting sources of negative impacts. This has particular implications for women who, across different countries and cultures, are predominantly the ones in charge of cooking which remains the source of high smoke emissions through burning of fire wood, charcoal and other polluting sources heavily used in energy poor contexts, both rural and urban (World Health Organization (WHO), 2016). In a study of Nigerian HHs' cooking energy use, Ifegbesan et al. (2016) observed that access to electricity demonstrated no significant association with the choice of fuel for cooking, confirming continued energy stacking practices post access to clean energy for uses other than cooking. In some places, traditional cooking fuels (such as fire wood) are chosen because of cultural preferences (e.g. Akintan et al., 2018), while in others lack of accessibility and affordability are an obstacle to clean cooking (and lighting) fuel choices (e.g. Atieno et al. 2018). To overcome the challenge of poor quality cooking which affects users' health (especially that of women), Zubi et al. (2017) have proposed a lithium-ion battery SHS in combination with an energy efficient multicooker to cover both cooking and lighting needs in energy poor areas of low-income countries. Such solutions have been explored before but their application has not been widespread to date, with relatively little discussion on their (future) potential in academic circles (Otte, 2013). Batchelor et al. (2018) have proposed solar electric cooker (PV-eCook) which they believe has a significant viability across Sub-Saharan African countries, and which could also be supported by the grid rather than solar PV only. Its pricing is predicted to fall to competitive levels against currently prevalent, polluting fuels in the next five years, potentially offering affordable alternatives to millions of HHs. Iessa et al. (2017) conducted a systematic review of literature on solar cookers and found four key issues regarding such solutions that can be noted: lack of proper consideration of local needs, existing cooking and fuel choice practices are an obstacle, there exists a pro-solution bias, and there is a lack of studies showing a methodologically sound impact.

Dutta et al. (2017) and the Alliance for Rural Electrification (ARE) in collaboration with ENERGIA (2017) have argued that women are the primary users and the primary beneficiaries of energy, yet their voices have been often missing from the energy access debates given that it is men who are traditionally in charge of decision-making in the HH and tend to be the HH representatives on issues around energy use. According to the authors, there should be more concerted effort to include women in those debates to fully understand energy use, as well as energy needs and aspirations of unelectrified HHs. In her study on traditional gender roles and perceptions of energy in Kenyan HHs, Fingleton-Smith (2018) found that there is often a disconnect between who uses energy and benefits from modern energy technologies the most, and those purchase them. The results of qualitative interviews revealed that due to traditional gender roles, men do not spend a lot of time at home whereas women do but their agency in HH decisions, including those regarding energy access, is limited. The men might therefore feel they do not benefit from improved energy access but are the ones targeted for purchasing energy technologies, such as SHSs. This point also speaks to the discussion on energy use behaviour (here referring to 'the who' of energy use) in section 2.5 and the energy needs and aspirations which can only be fully understood if all end-users are consulted, discussed in section 2.6

2.3 The access debate

When talking about access, IEA (2011) places stress on the 'connection', 'minimum consumption level' and 'increasing electricity consumption over time' thus pointing to access as something dynamic. It also acknowledges that there is no universally accepted definition of access (IEA, 2006). There have been, however, a number of frameworks to categorise it and the emerging discussion has revolved around the question of the level of access with a growing trend of moving away from the binary metrics (i.e. with access versus without access) (Nygaard et al., 2018) and towards multi-tier approaches, similar to that developed by ESMAP (2015)- the Multi-Tier Framework (MTF) (Figure 2.2), which has been the most commonly used since its conception.

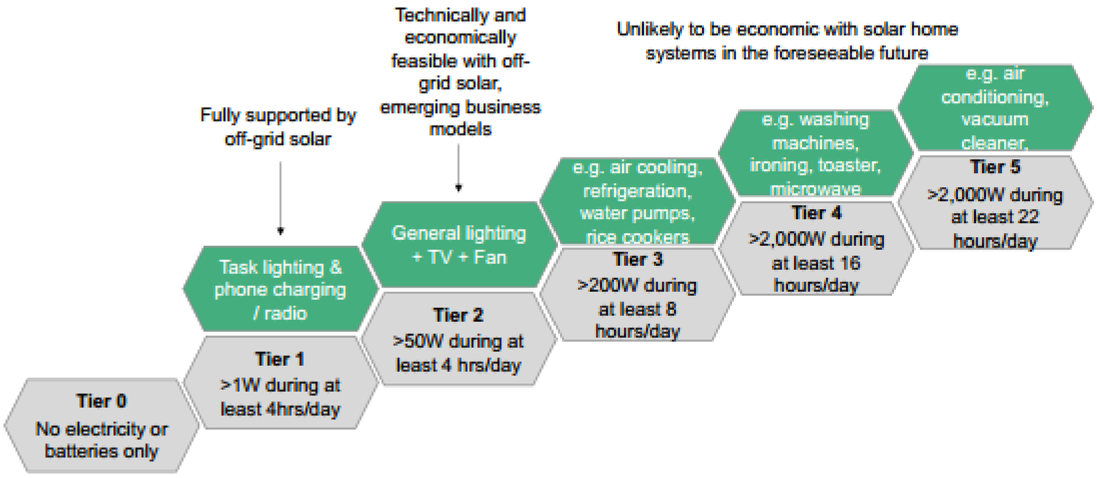


Figure 2.2. A multi-tier approach for access to household electricity services as defined by World Bank's ESMAP with indication of potential for off-grid solutions.[6] Source: Lighting Global and BNEF, (2016: 42).

According to the former, SHSs users fall in the "with access" category, however, according to the latter- they typically fall somewhere between Tier 1 and Tier 2 out of 5, depending on the size of the system they own. This means little beyond having only the basic needs satisfied, including lighting, phone charging and other basic appliances such as radios or fans, and TVs which tend to be aspirational and come at a considerably higher cost, often unaffordable to low income, rural households. Productive uses requiring higher levels of supply, such as for agricultural and industrial purposes, are also currently out of reach for SHSs. Figure 2.3 below demonstrates the IEA's (2017b) estimation on the level of support offered by the four most common energy access solutions. Even though SHSs can have the capacity to power off appliances for income generation (such as small agro-processing equipment or irrigation pumps), more energy-demanding uses remain beyond their scope. Bazilian et al. (2013) have argued that larger-scale solar solutions, offering thousands of kW scale, such as solar mini-grids, have already reached economic viability across many markets. In this light, they contend, SHSs should be seen as a short-term solution

[6] The MTF offers improved accuracy of data on the actual energy services provided to households. In addition to dividing access levels into 5 tiers, it also captures the granularity of energy access attributes such as capacity, reliability, quality, affordability, duration of supply, safety and legality (World Bank et al., 2017). For a full breakdown, see Appendix 2.

which should be replaced with options providing lower-cost, higher quality energy access as they become available (ibid.).

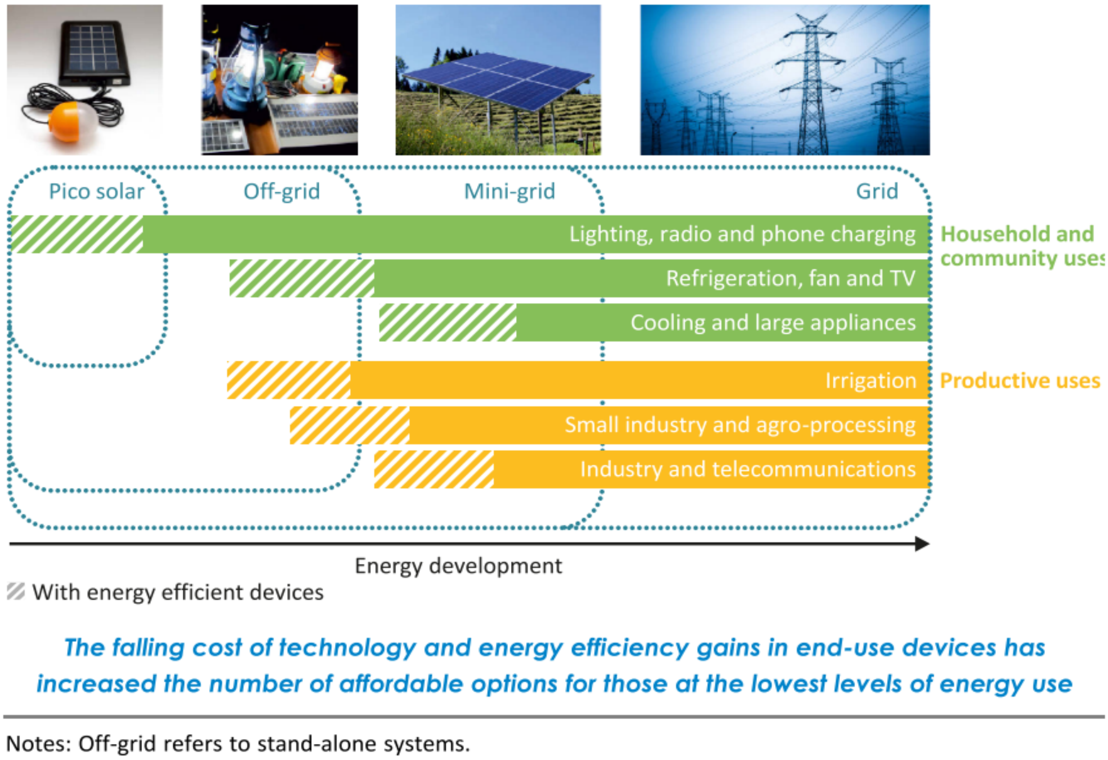


Figure 2.3. Electricity access and existing technology options, where off-grid refers to SHSs. Super energy-efficient appliances and innovation in the off-grid solar sector have increased the number of available options at the lowest levels of energy use. Source: ©IEA (2017). *WEO-2017 Special Report: Energy Access Outlook*, IEA Publishing. Licence: www.iea.org/t&c

Chattopadhyay et al. (2015) further argue that the history of electricity systems proves that more efficient generation resources that benefit from economies of scale ultimately tend to prevail. Therefore, "[…] individual household-based infrastructure will likely become suboptimal from a service and cost perspective" (ibid.: 43). However, despite the economic and physical viability of solar mini-grids for low-income consumers, such solutions, just like grid connections, might not arrive for years, if not decades, due to a number of challenges, including not enough demand, implementation, organisational and business models of mini-grid services, operation and maintenance of mini-grid facilities, institutional inclusion of such solutions in electrification strategies, and community buy-in (Ulsrud et al., 2018; Azimoh et al., 2017; Ulsrud et al., 2011). Bhattacharyya (2018) has also argued that due to mini-grid electrification being so far hardly embedded in the rural development agenda in developing regions, mini-grids have to date not contributed to livelihood generation in a significant manner. Despite offering potential for tier 3 upwards level of access (depending on the service offering, which could also not exceed that of SHSs), according to ESMAP's matrix, they may remain out of reach for many currently living off the grid, leaving market-based distributed solutions, such as SHSs, often the most feasible options in places where they are available (Hogarth & Granoff, 2015). Halder & Parvez (2015) have shown that users of SHSs in Bangladesh found their systems economically beneficial, in particular when used for small income generation as opposed to just lighting. GOGLA & Altai Consulting (2018) have conducted an extensive socio-economic study among 2,343 customers using SHSs of 7 different companies in Eastern and Southern Africa (Kenya, Uganda, Rwanda, Tanzania and Mozambique). They found that for 44% of users having a SHS enabled them to spend more time at work, 58% of households undertake more economic activities and 36% of households were found to generate additional income (on average $35 per month) thanks to their systems.

SHSs are easy to expand by adding more appliances (what is typically called 'upgrading') which can support a wider range of household activities without overloading the system (a standard capacity of a BBOXX SSHS, for example, is 50W meaning more appliances than solely lights, radios and mobile phone charging can be supported). In instances where solar mini-grids (or other types of mini-grids, including hybrid solutions such as solar-diesel) arrive in the area, households can subsequently switch to that source if their needs exceed the capacity offered by a SHS. This ideas has been coined as a 'solar energy ladder' (Chattopadhyay et al., 2015; RMI, 2015) challenging the more prevalent 'energy ladder' concept by pointing out the opportunities for an upward movement of energy use within off-grid provisions only[7]. In the context of plug-and-play, scalable SHSs, the 'solar energy ladder' can also mean upgrading one's system over time by adding new appliances which can be supported by a SHS and which can expand the range of energy services.

For these small-scale energy systems to best serve the off-grid populations, it is crucial to both understand their different dimensions of energy use, and to meet the users' needs and aspirations. Their successful application among households in places like

[7] The 'solar energy ladder' concept is further explored in section 5.1.3.

Bangladesh- the world's fastest growing off-grid SHS coverage where Grameen Shakti have been promoting access to energy through off-grid solutions since 1996, has proven the great potential of SHSs in addressing the energy poverty challenge (Halder & Parvez, 2015; Rahman et al., 2013; Khandker et al., 2014). Other successful dissemination of SHSs has taken place in Indonesia (Outhred & Retnanestri, 2015), Sri Lanka (Wijayatunga & Attalage, 2005), Myanmar (Newcombe & Ackom, 2017) and India (Singh, 2016; Harish et al., 2013; Buragohain, 2012), as well as in East Africa, which has seen one of the highest solar PV growth rates in the recent years (Harrison et al., 2016; Hansen et al., 2015). While the actual number of SHSs is difficult to estimate, they are present across all of Sub-Saharan African countries, with regional number variations (Urpelainen & Yoon, 2015). IEA (2017a: 4) have hailed SHSs as the "most dynamic sector in the off-grid segment" and predict that they will provide basic electricity services to as many as 70 million people in the SSA region and Asia in the next 5 years. Nygaard et al. (2018) have shown that the potential of decentralised off-grid solar solutions will continue on its upward trend due to falling prices and improvements in technology with ever more energy-efficient appliances, as well as innovations in business models which enable affordable access to those solutions.

2.4 SHSs business models

The SHSs market has seen a proliferation of various business models in the course of the last decade. With the availability of micro-credit and financial instruments to support the growth of energy service companies and innovative solutions allowing for servicing customers even in remote rural areas (Kabalci, 2015; Tejwani et al., 2014; GSMA, 2013), SHSs providers have adopted different models best suited to the context in which they operate (Guardo, 2018; Zerriffi, 2011). The most common business models include Pay as You Go (PAYG), Lease-to-Own, and Solar as a Service, which can include components of the first two models. The PAYG model has been particularly popular, allowing users similar flexibility to that offered by mobile phone services, on which the PAYG model has been based and which it often relies on (Sharma, 2017; Alstone et al., 2015; Nique et al., 2014; Smertnik et al., 2014; Rolffs et al., 2014), particularly in Sub-Saharan African countries where mobile services are widespread (Sharma, 2017). In this model, the user pays a price to purchase the SHS after which a daily/weekly or monthly fee is applied to use the system. This fee can be in a form of scratch cards, cash or mobile payments. Some of the key benefits it offers include lower barriers to adoption by end-users, transaction cost reduction (for the provider) linked to the digital payment method, and credit risk reduction associated with the real-time, remote monitoring (Reichert & Trivella, 2015). The PAYG model, as critical as it has been for the growth of the off-grid solar sector, is not without its challenges as companies effectively operate across two value chains: the retail/durable goods and the lending/leasing one. Such a set up poses at least three types of challenges, as argued by Sotiriou et al. (2018): strategic- is a vertical integration best for achieving the most optimal product and service offering? operational- requires competency in both hardware design and loan underwriting; and financial- difficulties in assessing performance of the provider involved in such a diverse range of activities. Though still relatively modestly researched, the PAYG model has been gathering more attention and receiving increased recognition for being better placed to facilitate poor people's access to sustainable, modern energy than other financing models (Rolffs et al., 2015) and for being better suited for supporting the distribution of basic and medium capacity SHSs (typically falling under Tier 1 and Tier 2 level of access) (Muchunku et al., 2018). In the context of Rwanda, Scaling up Renewable Energy Programme (SREP) have characterised SHS providers' variations of PAYG business models in the following way: "This [PAYG] model has two main advantages. First, it allows households to spread out payment for the equipment over a period of months or years to help make the systems affordable. Second, the systems installed tend to be more technically reliable and sustainable because the equipment suppliers enter into an energy services agreement with the households and remain responsible for the maintenance and servicing over a relatively long time period. Systems typically allow remote sensing to diagnose faults, and to terminate service if payments are not made, which helps to provide security to service providers and help manage non-payment risks. These technical innovations therefore help support financially viable business models." (Climate Investment Funds (CIF), 2015: 23).

In the Lease-to-Own model, there is similarly a purchase price and subsequent weekly/monthly payments (this varies greatly across all models). However, in this case the user owns the SHS after a certain period (usually 2-3 years of making regular payments). In both cases maintenance of the systems is typically provided for as long as payments are made, and systems are switched off when the user is late with their payment. In the Solar as a Service model, the company provides customers with a service but the SHS remains their property. There is a one-off installation fee and the service is then provided on a pre-paid basis, with the amount set at a level depending on the system capacity. The amount tends to be lower than in the Lease-to-Own model as the SHS (and all appliances that come with it, i.e. lights, mobile phone charging, radio, TV, fridge etc., depending on the company's range) remains the provider's property (Schäfer et al., 2014), or otherwise the control unit of the SHS remains the provider's property and the ownership of appliances is transferred to the customer upon repaying the full price of any given appliance. In those cases, maintenance is also included with the service.

Until early 2016, BBOXX fell in the category of Lease-to-Own provider, offering 3 standard packages (all including a battery box and a solar panel of either 15W or 50W): BB Lights (4 LED lights, 1 radio, 1 USB phone charger), BB Super Lights (5-6 LED lights, including 2 tube lights, 1 radio, 1 USB phone charger) and BB TV (4 LED lights, 1 radio, 1 USB phone charger, 1 15'' TV). However, recently BBOXX have introduced changes to their model, combining Solar as a Service and Lease-to-Own, as well as switching all their customers to a PAYG model to allow more flexibility of making payments- a decision driven by customers' feedback and repeated requests in surveys conducted both in Rwanda and Kenya. Currently, the customers get the appliances on a Lease-to-Own basis (they become their property after paying them off over a period of time) but the battery box and the solar panel remain the property of BBOXX (which was not the case previously- all hardware components' ownership used to be transferred to the customer after 3 years). Service is provided under the Energy Service Fee (ESF) which works as an insurance after the system has been repaid (in up to 3 years), as in the case of Solar as a Service model, but the appliances are no longer eligible for free maintenance once they have been paid off. Payment frequency is decided by the customer and now offers the possibility of repaying the three-years-worth of the SSHS in less time, if the customers is able to (e.g. he or she can make more frequent payments at higher amounts and get the appliances ownership in one or two years, rather than three, as was the case previously; likewise, he or she can make very small payments every day and continue over three years; each payment is treated as a top up/credit for the use of the system and the system gets switched off as soon as the customer runs out of credit/their top us is exhausted). The change gives BBOXX higher control over the batteries and the panels, and means continuous maintenance for the customers, but retains the ownership component of eventually owning the appliances, which has been found very desirable among the users. There is an added advantage of being able to choose the appliances the customer wants, instead of having to choose between the available set packages. Just like before, the system gets switched off in the case of no payment, however, now the switch off is dictated by the amount of top up the customer purchases (as explained above regarding top ups/credit) and thanks to SMART Solar it can be done remotely and instantly. The customer defaults (i.e. ceases to be a customer) if he or she does not top up for 15 consecutive days after the system has been switched off (every customer is given a grace period of 15 days without credit that he or she can use once every 4 months, so the total number of grace days over the course of a year adds up to 45). The system gets repossessed by BBOXX if at the time of default the customer's credit performance falls under 65% (paid versus due). If after the 15 days the performance is still above 65%, the customer will be allowed further grace days to top up and resume using the system.

The flexibility of payments on a PAYG basis also means satisfying the varied needs of a wide range of customers, including those who do not have regular incomes and would struggle to make set, regular payments otherwise (Zollmann et al., 2017). A lot of farmers in Rwanda have been found to struggle with that aspect of adopting a SHS, which is one aspect of the affordability challenge (Lenz et al., 2017; Grimm et al., 2014). By mimicking the way energy sources (kerosene, candles, batteries, etc.) are purchased in unelectrified households (i.e. as and when cash is available), it makes solutions such as SHSs affordable to the end-user on an on-going basis (Winiecki & Kumar, 2014).

2.5 Energy use behaviour

One of the sustainability challenges of SHSs is the sizing and the use of the systems. How and when people use the available energy impacts on the life span of the system, and particularly the battery component, which is the most sensitive to different energy use patterns. The most common types of batteries in SHSs are lead-acid and lithium-ion, both with an estimated longevity of up to 5 years (after which time, if used properly, without deviant charge-discharge profiles[8], should ensure sufficient capacity to support basic appliances that come with SHSs, such as light bulbs, mobile phone chargers, radios etc.). Azimoh et al. (2014) found that in South African communities where solar panel theft is prevalent, users resort to mounting the panels flat on the ground for protection and to be able to bring them inside at night, which has resulted in technical losses and poorer performance of the system. Such practices have caused the energy output and the battery performance to be compromised. System performance might also be compromised by using appliances incompatible with the SHS (which provides DC current rather than AC as in the case of grid connections), which might abuse the battery capacity and cause its rapid draining. End-user awareness raising and education on the use of the system might be required for controlling excessive loads put on such systems, as has been advocated by Gustavsson (2007) who studied SHS users in Zambia and found that with time more appliances have been added to the systems, increasing loads and impacting on the performance of the investigated SHSs. Phadke et al. (2015) argue that it is critical to keep expanding the range of super-efficient appliances compatible with the SHSs market offering in order to satisfy the growing needs of SHSs users, without considerable changes to system capacities (i.e. battery and panel sizes) which could lead to much higher costs. Bond et al. (2012) have argued that it is important to carefully size the systems and match the costs to the incomes of rural households in order to provide the needed level of access at an affordable rate. By testing the impact of three types of SHSs (10, 40 and 80Wp) in rural East Timor, they observed that even the smallest one provided most of the development impact of the two larger systems, with key uses being lights in kitchen areas. Bright, reliable lights have been found to be the appliances most valued by SHSs users, given their transformative impact on daily lives, including the reduction of kerosene and candles use for lighting (Stojanovski et al., 2017; Africa Progress Panel, 2017; GOGLA, 2016; Lemaire, 2016). The use of other appliances among SHSs users is often dictated by the availability of those in the provider's range

[8] A deviant charge-discharge profile is one that goes against the recommended, optimal usage and could be, for example, one where the system is never fully charged and constantly drained, disrupting the most efficient energy cycle, similarly as in mobile phones.

and the ability to pay for them (the more and the bigger the appliances, the higher the price of the system package). Lee et al. (2016) have examined appliance ownership and aspirations of both SHS-owning and non-connected households (primarily relying on kerosene for lighting), and compared appliances owned by those two groups to a sample of grid-connected households. What the study showed was that appliance ownership among the former two groups is similarly low, differing considerably from that of grid-connected users. Appliance ownership and availability has a major impact on the rates of electricity use. Greenstone (2014) has also identified it as one of the factors causing post-electrification usage rates to be low, along with the continued use of traditional fuels (such as kerosene, wood). Additionally, with prohibitively high initial investment costs required to get a grid connection (often upward of $100), the ability to purchase appliances decreases considerably, especially for bigger, more energy-demanding ones. Designing a diverse range of SHSs and appliances (as well as other alternatives to the grid, such as mini-grids and accompanying appliances), with different price intervals, will be crucial to ensure the whole spectrum of off-grid customers (and their demands) are served (Gilbert 2018; Chaurey & Kandpal, 2010).

Few studies focusing on the actual level of energy use and use patterns among SHSs adopters have been conducted. Energy fuels use behaviours, including pre and post adoption of modern energy sources (SHSs, mini-grid connections, etc.) and drivers behind them, including energy stacking practices and the non-linear nature of energy transition among off-grid households in developing countries, have been extensively studied (e.g. Sandwell et al., 2016; Opiyo, 2016; Treiber et al., 2015; Min et al., 2014; Baiyegunhi & Hassan, 2014; Lay et al., 2013; Maconachie et al., 2009). However, there has been less research on the actual usage patterns as monitored by the systems (more on remote monitoring of decentralised systems in section 2.8). Morante & Zilles (2001) studied energy demand among 18 SHSs using households in Ribeira Valley, Brazil, by developing a measurement instrument attached to each individual system. The results showed usage levels falling between 1-6 kWh/month, with a relatively high variation, loosely correlated with income levels (higher income-higher usage), geographical location (the more remote the location the lower the usage), and family composition (more members-higher usage). However, the drivers of energy usage patterns were found to be much more complex than the few factors considered in the study. The average 3 kWh/month per household also proves relatively low, particularly in comparison with other countries (e.g. approx. 1000 kWh/month per electrified household in the USA in 2014, approx. 120 kWh/month in India in 2014 and approx. 60 kWh/month in Ghana in the same year (IFC, n/d)). A study of 49 Cuban households connected to a multi-user solar system (MUS), which is comparable to a mini-grid, showed that individual household usage patterns varied depending on the number and type of appliances owned, and did not surpass 4 kWh/day (with a range of 1-4 kWh/day) (Jenny et al., 2006). Energy use behaviour among households showed five different profiles: 1) those using it all day, 2) evenings only, 3) mornings and evenings, 4) late mornings/midday and evenings, and 5) afternoon and evenings. Sandwell et al. (2016) have modelled basic and aspirational[9] energy demand using modern energy sources (SHSs) among rural households in Uttar Pradesh, India. They estimated it at between 1-3 kWh/day, depending on the time of the year (with longer hours of natural light in the summer and shorter in the winter impacting on the level of demand). Peak time, in each instance, was clearly demonstrated in evening hours, followed by night time use and day time use, which was noticeably less than in the previous two intervals.

2.6 Energy needs and aspirations

Aspects of energy needs and behaviours have been quite widely explored in the industrialised countries (e.g. Chatterton, 2011; Stephenson et al., 2010; Shove & Walker, 2010; Faiers et al., 2007) but less so in the context of developing countries. According to Tomei & Gent (2015), the definition of access to energy can vary depending on people's needs, wants and aspirations. Fulfilling these needs should be the key goal of these efforts to reach universal access provision. Bellanca & Garside (2013) also talk about the need to understand the aspirations, behaviours, preferences and economic conditions in order to design energy delivery models for low-income households. In its *Vision 2020* document, the Government of the Republic of Rwanda (GoR) (2000) acknowledges that in all aspects of its country development strategy it aims to meet the aspirations of the Rwandans. Understanding what these needs and aspirations are, and how they can best be met, can impact on the success or failure of

[9] Aspirational demand included demand stipulated by appliances which households indicated they aspired to own in the future. Basic demand was that of appliances currently used and supporting basic energy needs, such as lighting.

technology innovation adoption (Akrich, 1995). Historically, in household energy provision attempts have focused on the service, "without understanding […] aspirations or realities of the targeted beneficiaries" and how that shapes their energy choices (Pachauri & Spreng, 2011: 7502).

Needs and aspirations, as well as energy use patterns and wider energy use behaviour vary and may change over time. In the study of Indian slums, Parikh et al. (2012) discuss how access to energy services has shifted slum dwellers' social aspirations from lower to higher order. Howells et al. (2010) argue that having access to information can change consumers' customs, attitudes and aspirations by affecting the utility associated with the appliances usage which in turn impacts on the level of demand. As both providers and customers rarely have access to full information, the decision making is made according to the 'rule of thumb' and, to an extent, on assumptions. Even when information is available, it takes time to assimilate it and act upon it, however, it will still influence the service offering as well as the usage behaviour and shift in aspirations (ibid.). Having examined the 'user-perceived value' of electrification, Hirmer & Guthrie (2016) conclude that understanding the real needs and desires of the end-users (or prospective end-users) is critical to avoid shortfalls in technology uptake and to ensure the longevity of the offered service (or product) by selling what is truly valued. As they argue, "[u]nderstanding why something is important to the end-user will usually lead to an improved understanding of how a development initiative can be beneficial for a lower-income market" (ibid.: 487). The same authors in their 2017 publication (Hirmer & Guthrie, 2017) have looked at the user-perceived benefits of energy appliances and the results shown that the ones ranked the highest were "[…] business opportunity, elimination of labour intensive tasks, preservation of health, protection from people posing a threat (personal security), operational expenditure, ability to acquire knowledge, feeling comfortable, food security, information access, time savings and productivity improvement" (p. 924). These benefits also reflect what the most important needs are and what end-users expect to get out of accessing energy services through various appliances that might be available to them.

In their study of solar mini-grid users in India, Ulsrud et al. (2011) examined local dynamics and interactions of an electricity supply system, including types of knowledge, visions and aspirations of the people and institutions involved. A series of qualitative interviews with the users showed that growing overuse of electricity caused growing aspirations for increased supply which proved challenging to the service provider (the state agency West Bengal Renewable Energy Development Agency (WBREDA)) and its staff who tried to meet the expectations of the local communities. What the authors conclude is that the service provider managed to deliver power supply in a way that raised awareness of the usefulness of electricity thus increasing demand- a sign of shifting aspirations.

Some studies have demonstrated that, for example, pico-PV products fail to meet actual customer aspirations (and needs), even though they are an effective substitute of kerosene (Hirmer & Cruickshank, 2014a; Schützeichel, 2015). The needs of users of pico-PV (or solar lanterns, in other words) can barely be satisfied by the small capacity offered by pico-solar solutions which leads to shifting aspirations for bigger systems and/or energy stacking practices where various needs are satisfied with the use of different sources. The supporters of the technological leapfrogging theory claim that as off-grid customers gain access to modern solutions (such as SHSs or solar mini-grids), they can altogether skip the grid connection as these alternative solutions will provide enough supply to meet the needs (e.g. Zerriffi & Wilson, 2010). However, opponents of this view stress the problem with meeting the ever-growing demand and shift of aspirations that come with the initial access, and which call for the level of access that can only be achieved through the grid (e.g. Lee et al., 2016; Baurzhan & Jenkins, 2016). Alternatively, as in the case of South Africa, the predominant energy aspiration among off-grid communities is to have grid connection as it not only means a higher social status, but is also seen as the right of all citizens that should be taken care of by the government (Jobert, 2011). In this instance, technological leapfrogging is less feasible and the use of solutions such as SHSs can only be seen as a temporary remedy for accessing power.

Lee et al. (2016) have explored the appliance ownership and aspirations of SHSs users in rural Kenya and found that households differ in terms of their aspirations but overall SHSs are not a sufficient substitute for grid power which is still desired by the users, particularly as the most aspirational appliances are TVs, irons and refrigerators- the latter two being hardly supported by average SHSs at this point in time. Meeting demands for productive uses has been emphasised in relation to SHSs users and their needs (Brew-Hammond, 2009; Wamukonya, 2007). Contrary evidence was given by Gustavsson & Ellegård (2004) who found that social benefits (such as entertainment and socialising) provided by SHSs were more attractive to users in Zambia than productive appliances, though the likelihood of these findings to be outdated has to be acknowledged, as has to be the local context and lack of consistent ways of measuring impact and HH-level benefits. In a more recent randomised experimental study in Kenya, Lee et al. (2017) found low demand for grid connections and limited socio-economic impacts of electrification on rural households. It is important to recognise such divergent perspectives and crucial to understand how needs and aspirations are shaped and change over time to offer an adequate service to off-grid households now and ensure a well-tailored service in the future. In their Poor People's Energy Outlook (PPEO) series, Practical Action have advocated a bottom-up methodology which takes "[…] an end-user needs approach to national rural energy planning and financing", i.e. putting people at the centre of energy planning, in order to realise off-grid households' and communities' diverse energy needs and aspirations, and ensure sustainability of energy access solutions" (Practical Action, 2017: 11). Those should not only address electrification but also clean cooking, which is currently not (fully) supported[10] by OGS, and which poses a critical need in SSA where over 700 million people rely on traditional, polluting cooking fuels (Ngum, 2016). In the *Poor People's Energy Outlook,* Practical Action (2016: 11) proposed the 'Total Energy Access' framework which encompasses three domains of energy access: at the household level, for productive uses (work place), and for community facilities, differentiated by gender. It also incorporates different forms of energy access, i.e. electricity, cooking, heating and mechanical power via grid connections, mini-grids and stand-alone systems, such as SHSs (ibid.). This approach recognises the complex nature of energy access and its numerous components, as well as the range of needs which exist in unelectrified environments, going beyond household-level only.

[10] There exist solar biomass cook stoves, such as ACE1 (see: http://www.africancleanenergy.com/product/ace-1-cookstove/), however, they tend to be expensive (approx. $150). There are currently no exclusively solar-powered cook stoves on the market the author is aware of.

2.7 Customer satisfaction with SHS

Van der Vleuten et al. (2007) mention the importance of customer satisfaction to SHSs providers as favourable customer feedback from customers can highly contribute to the promotion of their systems, given a lot of it happens through the word of mouth. Tamir et al. (2015) acknowledge the role of sizing of SHSs, which should be based on load demand and available resources (as also discussed in section 2.5), in achieving high levels of customer satisfaction. Schillebeeckx et al. (2012) quote the WB case study of Sri Lanka which showed greater satisfaction among grid users than users of PV systems because of insufficient supply, noting that grid users consume on average six times the amount of electricity of SHSs users, which may be the reason for higher levels of service satisfaction. The existing studies of customer satisfaction of SHSs and frameworks used also reveal that it is important to examine both satisfaction with the product and the service (with a particular stress on the after-sales or post-implementation services) as both are valuable indicators that can contribute to significant improvements at the providers' end and thus to increased overall satisfaction at the customers' end. Momotaz & Karim (2012) conducted a 'Service Quality' (SERVQUAL) customer satisfaction survey among users of SHSs in Bangladesh with the results showing most consumers satisfied with their SHSs. The SERVQUAL model uses the concept of the 'service quality gap' between the expected and the actual level of service delivery as experienced by customers. In the study, there was little existing gap between expectations and perceptions of the systems among the users (ibid.). Another study of customer satisfaction among SHSs users in Bangladesh showed an overall high level of satisfaction at the same time revealing the aspirations for full ownership of the systems, which was often impossible due to insufficient income levels (Khan & Azad, 2014). Full ownership is a contentious issue as, on the one hand, it is desired by adopters of SHSs (Pode, 2013) while, on the other hand, it carries with it a number of risks. For example, the transfer of responsibility for the system's operation and maintenance (O&M) to the household might pose challenges due to the associated costs (Schillebeeckx et al., 2012). Systems going into disuse as soon as they break down, as a result of lacking maintenance services and no local capacity to fix it has been another challenge and a threat to the sustainability of SHSs (Yaqoot et al., 2016). In her systematic review of HH solar adoption, Girardeau (2017) found that customer support and ongoing maintenance can increase sustainability and continued use of solar technologies.

In Sri Lanka, Laufer & Schäfer (2011) conducted a qualitative survey among 40 users of SHSs and found users stressing an improved quality of life as a result of having access to electricity but at the same time were often dissatisfied with the limited capacity of the systems and experienced various functionality issues. A survey of SHS users and implementers in Fiji by Urmee & Harries (2012) revealed problems with post-installation services and the quality of system components- factors which have a critical impact on customer satisfaction. Mulugetta et al. (2000) have stressed the importance of understanding if people's expectations have been met by SHSs and therefore the need for addressing the issue of customer satisfaction, including focus on both expectations and after-sales support requirements for breakdowns and malfunctions. Even though the study was conducted in very early days of SHSs, it stresses points on after-sales support and maintenance which still carry importance today (e.g. Ngoepe et al., 2016). In a study of SHS users in the context of remote areas of French Guiana (Linguet & Hidair, 2010), surveys were conducted to better understand the attitudes, expectations and users' relationship with their systems. Levels of satisfaction with the system operating efficiency and maintenance services were measured and the results showed that customers were dissatisfied with the installation services of the provider, which was further exacerbated by system failures and incorrect uses of available appliances by the customers.

Measuring customer satisfaction can be applied to the design and continuous improvement of service provision and customer relationship management strategies. Schelling et al. (2010) contend that customer satisfaction of SHSs increases the chances of regular payments and the full payback of monthly instalments. Another important aspect that needs to be considered in order to achieve higher willingness to pay among SHSs users is the provision of maintenance services. Dissatisfaction with the lack of servicing of even the smallest parts of the system may cause user dissatisfaction and lead to the reduction of incentives for continued repayment of the fees (Nieuwenhout et al., 2000).

User satisfaction is considered to be one of the crucial elements for establishing strong rural solar PV markets and measuring levels of satisfaction has been seen as a "[…] comprehensive indicator of the perceived benefits of equipment quality and usage, and of the benefits of electricity supply on the quality of life" (Komatsu et al., 2013: 53). It also helps promote focus on customer outcomes and can better stimulate changes and improvements in the practices of the service provider (Bhave, 2002).

Monitoring of customer satisfaction with SHSs is a complimentary component of studying users' needs and aspirations, showing what the key aspects of satisfaction and dissatisfaction are, thus indicating key areas of potential improvement. Measuring customer satisfaction can also expose issues such as insufficient user capacity, as was the case among users in French Guiana (Linguet & Hidair, 2010). Ensuring high levels of satisfaction with energy solutions may also help with faster dissemination as users' willingness to recommend them is expected to grow the more satisfied they are (Schützeichel, 2015; Kebede et al., 2014; Schelling et al., 2010; van der Vleuten et al., 2007; Wamukonya & Davis, 2001).

2.8 Remote monitoring of decentralised systems: approaches and challenges

Remote monitoring of solar PV systems has recently gained importance, particularly among private market providers of SHSs and solar mini-grids (e.g. BBOXX, M-Kopa, MeshPower). The technology ensures continuous monitoring of systems' performance, battery health and energy use patterns, instantly detecting any faults or irregularities. This kind of information gives the provider an opportunity to carry out preventive maintenance to improve performance and the life of the systems, thus not only reducing the operating costs, but also reducing the need of users' intervention in case their system fails (Tejwani et al., 2014). The most popular techniques of remote monitoring include a computer to computer communication, embedded system to computer (GSM), and embedded system to embedded system (GSM, GPRS) (ibid.) (commonly called machine-to-machine (M2M)). The rapid expansion of mobile services in Sub-Saharan Africa has been particularly favourable for GSM applications (Schäfer et al., 2014). Energy access is affected by mobile services in three ways – as a financial gateway to unbanked customers; as a service allowing technological system innovations, including remote monitoring; and as a technology offering insight into customer data and feedback which enables more effective user-centric design practices (GSMA, 2015).

Real-time, remote monitoring of both SHSs and mini-grids (its cost being too high to apply to pico-solar solutions) highly contribute to the viability and effectiveness of PAYG models of provision (Rolffs et al., 2015; Reichert & Trivella, 2015). However, its functionality depends on the prevalence of mobile money utilisation among end-users, which is a necessary prerequisite for PAYG payment systems to work. In a field test of such application to a micro-hydro mini-grid in Rwanda, Njoki & Waters (2016) have observed that the lack of universal access to mobile money made it difficult to switch to fully cashless operation which was one of the ambitions of the test- an outcome that would lower the risk associated with direct cash collection and customer default. Another challenge was the cost of the remote monitoring, payment and control systems. However, despite the problems encountered, the practitioners involved in the test suggest that as the number of mini-grids increases, the demand for such integrated solutions is likely to follow and service providers should attempt to continue to innovate for affordable, user-friendly technologies which also offer improved economic viability for this kind of energy projects. Same can be said about the growing market of SHSs.

In terms of the actual way of using remotely monitored SHSs (SMART SHSs, or SSHSs, in this study), there is no noticeable difference for the users as the technology is embedded in the system. However, the benefit of receiving improved maintenance service and having a system better adjusted to the specific energy use behaviour may have a significant impact on the users' experience of SHSs. Such technologies also offer a high-resolution data on the actual use of energy, providing insights on the energy use behaviour and the ability to learn about patterns of energy usage over time.

An elaboration on the use of remote monitoring and the details of the technology in the case of BBOXX can be found in the appended article co-authored by the researcher (Bisaga et al., 2017) (see Appendix 14).

2.9 The energy behaviour frameworks

A number of analytical frameworks has been considered for this study. While looking for the most appropriate framework given the scope of the research, factors such as relevance for analysing energy behaviour, inclusion of socio-cultural and economic factors, and applicability to the context of developing countries have been prioritised. The 'Energy Cultures' framework proposed by Stephenson et al. (2010) was one which fitted the criteria (Figure2.4).

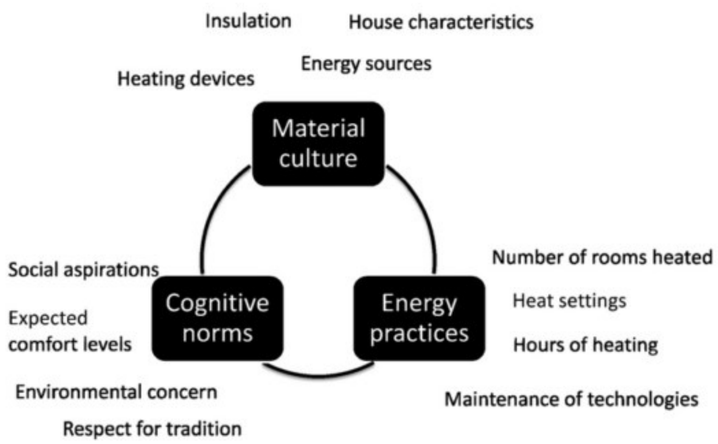


Figure 2.4. The Energy Cultures' framework (Source: Stephenson et al., 2010, p. 6124).

The most useful characteristic of the above framework was the explicit inclusion of social aspirations in the analysis of energy behaviour. However, this framework is more suitable for characterising behaviours such as home heating or energy-saving in the household as it has been created with the focus on modern households in the developed world. It was, therefore, not best placed for this study but it has been a useful point of reference for introducing adaptations to the selected framework (introduced below). The two also show many similarities in that both highlight the dynamic relationship between the different components making up the complex reality of the subject(s) under investigation.

The three-dimensional energy profile conceptual framework for assessing household energy use developed by Kowsari & Zerriffi (2011) was the other most suitable framework and has been chosen as the analytical tool for this study (Figure 2.5).

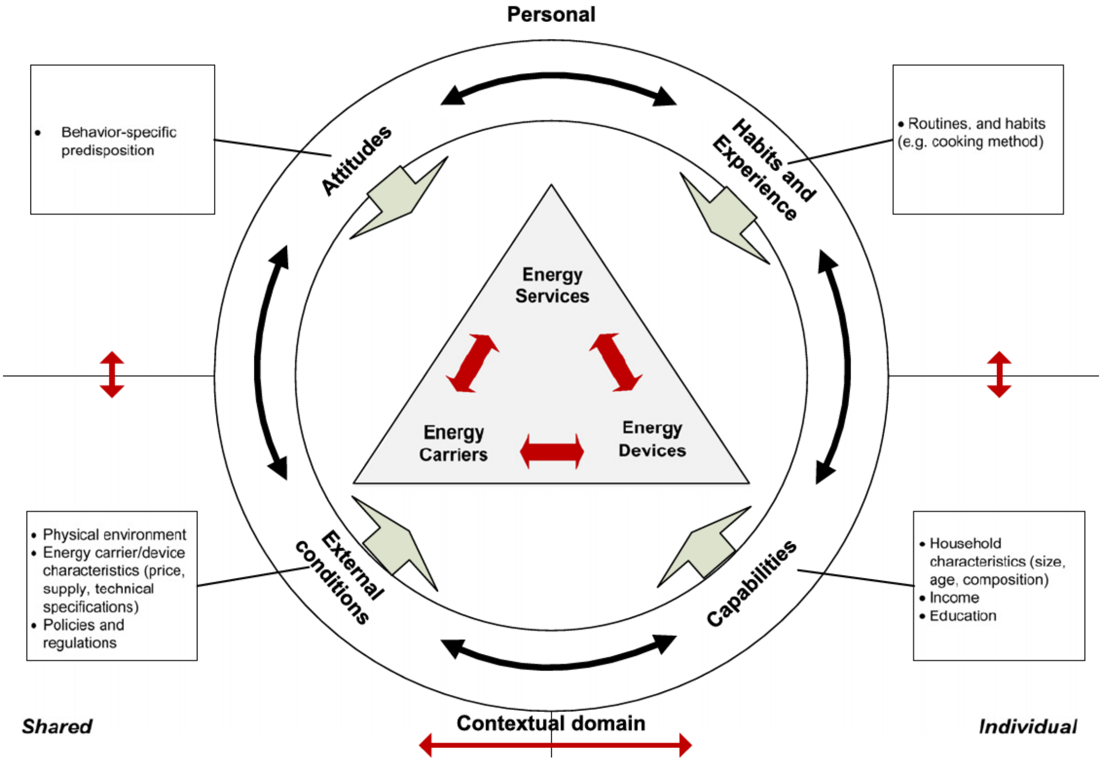


Figure 2.5. A three-dimensional energy profile illustrating the exogenous and endogenous factors influencing the profile (Source: Kowsari & Zerriffi, 2011: 7514).

The framework offers the opportunity to create new theoretical and empirical models of how rural households use energy (ibid.), which suits the scope of this study's goals. It incorporates a complex but comprehensive set of interacting spheres which shape the household energy use, focusing primarily on the energy services rather than energy quantity, and offers room for a rich analysis of socio-cultural, behavioural, economic, technical, and physical factors that impact on how energy is used, existing needs and aspirations built, which all make up what the authors call "the human side of energy use" (p. 7514) under the personal domain (both attitudes and habits and experience). In demonstrating those complex interactions, it stresses the multi-dimensional nature of energy use, not least in terms of energy services, devices and carriers, but also in terms of the various dimensions of spaces and places where energy use occurs. This feature of the framework relates it to the 'Social Practices Approach' (Spaargaren, 2003) which sees consumers' behaviour as enabled, constrained and contextualised by systems of provision. In that way, 'social practice' refers to a domain of daily life, such as food, cooking or bathing (ibid.: 696) (under 'habits and experience' in the framework), which are sites in which systems and behaviours interact (in Shove & Walker, 2010). Moreover, in this way the framework also enables links to the socio-technical change perspective on the 'co-construction' of user practices and (energy) technology where "[…] technologies are adjusted (in smaller and larger steps) to fit better with the user environment [while], on the other hand, the user environment (user practices, behavioural routines, infrastructures, policies, etc.) is adjusted to accommodate the new technologies. In this way, technologies, environments and user practices co-evolve" (Geels et al., 2018: 25). Even though the socio-technical tradition in energy studies has mostly focused on socio-technical transitions to sustainable means of energy provision, use and demand (or low-carbon transitions), mostly in high-income and urban settings (e.g. Geels et al., 2017; Adil & Ko, 2016; Geels, 2011), the approach is relevant for this study in that a new, low-carbon energy technology is introduced into a new social setting, becoming an alternative to the traditional means of energy provision (i.e. the grid) and integrated into a context where to date the most commonly used energy sources have been candles, kerosene and batteries, with occasional grid connections, frequently unreliable in nature. The introduction of new technologies for energy access, such as SHSs, solar lanterns or solar mini-grids, have been made possible particularly in places with a strong regulatory support (the contextual domain of policies and the regulatory environment), of which Rwanda is one example, and their adoption and use are shaped by the various habits, practices and behaviours in predominantly rural and/or peri-urban settings of low-income countries. As put by Geels et al. (2018), the systems are called socio-technical as "[…] they involve multiple, interlinked social and technical elements, such as technologies, markets, industries, policies, infrastructures, user practices and societal discourses" (p. 24). Additionally, a transitions perspective also acknowledges specificities and complexities of the types of change processes involved, effectively creating new socio-technical systems (ibid.). This is also where the role of the community is considered as another space where energy is accessed, and energy solutions are considered. Community perceptions and awareness of energy access solutions can impact on the spread and adoption of energy technologies (i.e. household decisions) and vice-versa: individual households' decisions and use of energy technologies can impact on community dynamics, raising awareness but also questions of equity as selected households graduate on the energy ladder, or staircase, while others do not, whether due to cost or otherwise. This study addresses those complex interactions through the applications of the three-dimensional energy profile framework, and by exploring questions around household energy systems use behaviour, needs and aspirations, as well as satisfaction with new energy technologies and the impacts they have on the household. It also aims to demonstrate how the social aspects of energy access can inform the technical, as well as policy and regulatory environment (which are components included under the interactive personal and contextual/shared domains). It examines community perceptions of solar energy access solutions and briefly looks at the intra-community dynamics related to the adoption and use of SHSs by rural households, which fits under the contextual domain of the three-dimensional energy profile framework.

Furthermore, while considering income as one of the determining categories under capabilities, and energy technology under external conditions, the framework does so while giving the same weight to other factors and impact categories. This fits with the aim of this study, where a more balanced approach has been assumed in order not to overemphasise the techno-economics of energy access, but rather give recognition to all different aspects, including socio-technical, socio-cultural, techno-economic and political (or regulatory), as described above. Additionally, it "addresses energy use at the most disaggregated level, the household, and can be used with both quantitative and qualitative data" (Kowsari & Zerriffi, 2011: 7514). In this regard, it matches the mixed research methods design and the unit of analysis (i.e. the household and its members) applied to this case study. While laying out firm domains (personal and contextual) and categories (attitudes, habits and experience, external conditions and capabilities), it provides the option for the researcher to choose which domain and which category are to be explored in the most detail to answer the questions posed in this study.

Another important aspect is the presence of energy carriers, energy devices and energy services at the heart of the framework, which the authors collectively call the 'Household Energy System' (ibid.). Household energy behaviour depends on decisions made on all three dimensions of energy, and on the interactions with them, which aligns both with the social practice approach and the socio-technical transitions one. In the case of users of SSHSs, the energy services would be those provided by BBOXX, the energy devices would be the SSHSs with the accompanying appliances, and the energy carriers would be solar energy. As much as the energy carrier (solar power) is a set dimension for all users of SHSs, understanding the experience and use of energy services and devices will be a crucial component in this study. Attitudes towards energy carriers among users of SSHSs will help to understand their perception of solar energy and if they believe it can satisfy all their current and future needs, eventually helping to shape the design of energy carriers, devices and services.

The social practice approach through Social Practice Theory (SPT) is further elaborated in this study in order to gain a better, in-depth understanding of the interactions with energy services, devices and carriers, and specifically to gain insights into how social practices associated with gaining access to an improved energy source (here off-grid solar energy) change, evolve or disappear. SPT, first put forward by Schatzki (1996) and further developed by Reckwitz (2002), draws on the critical social theory of Bourdieu and Giddens (1984) which explore practices (i.e. routinised forms of behaviour) and their roles in structuring daily lives and social systems as a whole. Within the different strands of practice theory, the common thread is the collective nature of practices, here applied to a collective structure of a household and, to a lesser extent, the wider community. The recognition of the role of material configurations appeared in the later works of Schatzki (2001) and was emphasised in the work of Shove et al. (2012) who stressed the importance of things and materials (or artefacts in Latour's Actor-Network Theory (2005)) in everyday life. Both living and non-living things are seen as active agents in the society whereas people are not only agents but also 'practitioners' who combine three elements making up practices, namely: materials (physical objects), competences (the know-how) and meanings (the symbolic meanings and aspirations), in a similar way as in Stephenson et al.'s (2010) Energy Cultures framework. In SPT terms, people practice energy by engaging in various activities and behaviours which require its provision, lighting and watching TV being an example.

SPT stemms from a critical social theory tradition and the three-dimensional energy profile framework is predominantly based on development (socio-economic) and behavioural theories rooted in psychology, yet despite this theoretical contrast there is an overlap in how both place, on the one hand, the spatio-temporal nexus of doings and sayings (SPT) and, on the other, the spatial domain where energy behaviours exist, at the centre. Additionally, both recognise the hardware (material objects and energy devices in the case of the three-dimensional model) and their interactions with competences and meanings, collectively and individually, which in Kowsari and Zerriffi's framework are demonstrated in the personal and contextual domains, with a distinction between individual and shared (i.e. collective), where energy behaviours exist, which is also where energy practices are formed and shaped, both at an individual and collective level. This convergence has provided an opportunity to combine the two for a deeper understanding of energy use among households gaining access to a modern energy source for the first time and experiencing changes which are also manifested in shifting practices.

Due to the primary three-dimensional energy profile framework taking a systemic view on energy behaviour, systems approach for data collection design has been assumed, which left the researcher with a high level of flexibility and opportunity for exploration of various themes, or categories, and the interactions between them. The multidimensional nature of the framework further allowed for investigating the question on the energy use behaviour and experience of SSHSs users, and the SPT lens has enabled the analysis of the 'practice of energy' among the participating households (Chapter 5), thus enriching the study in a predominantly qualitative way (though with the use of quantitative data) and the application of a competing yet complementary framework with both recognising the importance of interactions between the users and the energy devices and services.

The main limitations of the framework include its composite structure and visualisation (at least initially), and the lack of explicit inclusion of social aspirations and needs in the proposed method of analysis. However, both have been added and incorporated under the 'personal' domain, focusing on all three aspects of energy: carriers, services and devices, with the latter two given more consideration. This addition was key to the study. The framework's conceptual foundation is similarly complex and lacks clarity, making it challenging to apply in a systematic manner, particularly due to a somewhat ad-hoc selection of concepts included under the personal and contextual domains which make it difficult to interpret (some) data and observations. This could be a result of the wide range of theoretical foundations on which it has been built and/or the endogenous and exogenous factors, as defined by the authors, being only presented as examples rather than a comprehensive set of factors determining and impacting on the energy use. A careful consideration of all proposed factors and a deliberate addition of those deemed missing have been performed to address this challenge. With only a brief acknowledgement of social power relations (at a household level but not at a collective one) and the absence of issues concerning energy justice, the framework ignores some of the critical questions around energy access, including the moral and equity dimensions of energy production and use (Sovacool et al, 2017) within and outside of a household. This aspect has been briefly accounted for in this thesis under the personal domain chapter through the analysis of the (in)sufficiency of off-grid solar energy provision. Finally, there is a lack of an explicit incorporation of a social status into the set of factors determining energy profile, despite the role it can play in accessing and using energy, as well as the way in which it can influence changes in energy systems. Again, a brief examination on this, particularly within community structures, has been included in the study under the contextual domain (Chapter 4).

Despite the above-mentioned limitations, which have either been acknowledged or adapted for the purpose of presenting as comprehensive as possible analysis of the collected evidence, this analytical framework guides the structure of the findings chapters (Chapter 4 and Chapter 5), first focusing on the contextual domain and its components, followed by the personal domain and its components. Each chapter contains a brief summary and discussion which is then elaborated in Chapter 6.

Chapter 3 Research Methods and Methodology

This section will discuss the research methods and the methodology the researcher has applied to answer the research questions posed in section 1.5. It has utilised both qualitative and quantitative research methods, jointly called mixed research methods within a case study design, and a pragmatic approach to knowledge generation has been assumed. It is important to note that this research project has been carried out in collaboration with BBOXX, focusing on the users of SMART SHSs (SSHSs) in Rwanda as provided by the company. Collaboration with BBOXX has ensured access to both users of its systems and data from the SMART Solar platform. It has also helped with on-the-ground logistics of reaching the users who often live in remote, rural locations and the mountainous landscape of Rwanda makes it particularly challenging to gain access.

3.1 Research methods

Yin (1994) describes a case study as an empirical enquiry that investigates a contemporary phenomenon in a real-life context, where the investigator has little to no possibility to control the events. According to Eisenhardt (1989: 534), case study is "[…] a research strategy which focuses on understanding the dynamics present within single settings." It is seen as a suitable research design for studying complex social phenomena, allowing for exploration of multiple variables, multiple sources of evidence and different theoretical propositions to guide data collection and analysis (Yin, 1994; Baxter & Jack, 2008). It also benefits from mixed research methods which help to answer questions "how" (common in quantitative studies) and "why" (common in qualitative studies), which are prevalent in a case study (Yin, 2014), and which have been used in this study to answer questions about SSHS users' energy behaviour and practices. The researcher also believes that both quantitative and qualitative forms of data are useful and necessary for verification and generation of knowledge and theory, in accordance with Glaser & Strauss (1967) and Eisenhardt (1989), and for assuming a complex view of the world in a way pragmatic approaches[11] do. Tashakkori & Teddlie (2003: 713) define pragmatism as a "deconstructive paradigm that debunks

[11] See section 3.3 for the elaboration on pragmatism, which has guided this study.

concepts such as "truth" and "reality" and focuses instead on "what works" as the truth regarding the research questions under investigation, […] and acknowledges that the values of the researcher play a large role in interpretation of results."

Additionally, a case study is a well-suited method for an exploration of the complex nature of energy behaviour and practices (the "phenomenon") among SHSs users (a diverse rather than homogenous group) and the various socio-cultural, economic and physical factors that impact on the users, their behaviour, their experiences as well as needs and aspirations. The unit of analysis in this case study is a household where these factors interact and where users experience their SSHSs, thus forming their own different and complex systems (interdependent parts forming an integrated whole), which should provide a rich picture for analysis.

The adoption of mixed research methods has been driven by a number of factors, including:

i) The use of data collected via the SMART Solar platform (quantitative), which was to make up a part of the project from its inception given the valuable insight it provides into the users' energy behaviour from the technical perspective;
ii) The value of surveys in reaching high numbers of customers and identifying key themes related to their energy needs and aspirations, as well as in measuring their satisfaction with the systems and the service they receive;
iii) The value of face-to-face interviews and focus groups, as well as ethnographic studies in further exploring the identified themes (Creswell, 2003);
iv) The additional qualitative value offered by participatory photography, complimenting interviews, surveys and focus groups. By allowing SSHS users to present their reality through the lens of a camera, participatory photography reveals aspects of their daily reality which might be challenging or impossible to uncover through other, more traditional research methods;
v) The suitability of mixed research methods for a case study design and the ease of creating scope for data triangulation (and methodological triangulation) with multiple data sources, data collection and analysis procedures (Cresswell, 2014). Methodological triangulation refers to "the use of multiple methods to study a

single problem" (Patton, 2002: 247), which in turn refers to the application of mixed research methods in a study.

The study has followed an inductive-deductive logic with a sequential design, which are common in mixed research methods (Teddlie & Tashakkori, 2008). The first survey (Survey 1), including both quantitative and qualitative components, was conducted among 126 users of SSHSs in Rwanda. Its findings were the first steps in the research cycle whereby in a deductive manner an a priori hypothesis on the impact of remote monitoring of the SSHSs on customer satisfaction was not supported due to the negative evidence (no correlation between remote monitoring and overall customer satisfaction was found) while at the same time new themes emerged through inductive inferences. Throughout the duration of the study, as data was collected and analysed, and observations made, the cycle of inductive-deductive logic continued to finally build a novel theory around users' energy behaviour. It has followed an explanatory sequential design in that various core strands of the study (surveys, in-household interviews, focus groups, participatory photography etc.) took place in a chronological order (other than stakeholder interviews which took place over a period of a few months and often at the same time as other data collection was ongoing; they did not form a part of the core strands of data collection, and instead offered background information on policy and practice in the off-grid solar sector in Rwanda). Each strand was used to guide the design of the one that followed (e.g. sampling and data collection methodology) (Engel & Schutt, 2014).

3.1.1 Data collection

Data collection instruments have been designed using a systems approach to build a complex, rich picture of the case study. Soft-systems approach is particularly useful for a study where understanding human behaviour and human systems is crucial as it "views social systems as constructed by individuals and strives to understand and respect the perspectives of those individuals rather than studying the system as if observed from the outside" (Watson & Watson, 2014: 5). According to Checkland (in Wastell, 2012: 2), soft-systems methodology "assumes a fluid social world, one which persists and changes, continuously socially created in never-ending social processes." The recognition of those processes and their complexities in any given reality makes for a useful tool when attempting a deep exploration of the subject. Given the scope and the aim of this study, soft-systems approach has been found a useful and appropriate one to adopt.

Data collection instruments, in addition to surveys, included focus groups which are a useful instrument for exploring ideas (Cresswell, 2014). A total of 10 focus groups have been conducted in different parts of Northern Rwanda, using the help of local BBOXX shops (Shop Managers, Retail Managers and Sales Agents) to recruit participants. They were flexible in format, without rigidly set questions (see Appendix 4 and Appendix 5 for sets of questions used in Focus Groups 1 and Focus Groups 2, respectively), so as to allow discussion among the participants (Kitzinger, 2005). The role of the researcher was to facilitate discussion with the help of a Research Assistant. The findings of the first 5 focus groups guided the design of 97 face-to-face interviews (Survey 2) with the users of SSHSs, chosen through purposive sampling to ensure they were in places the researcher and her assistants could get access to and so that they would be available at the time of the interview (see Figure 3.1 below for their locations). The following survey (Survey 3), with an edited set of questions (mainly by adding multiple choice responses to the original script used for Survey 2 but otherwise unchanged)[12], was conducted with 169[13] users of SSHSs after focus groups and in-household interviews had taken place, gathering additional quantitative and qualitative data to complement the study. This was done via telephone (like was the case with Survey 1) with the help of two Research Assistants who were involved in the prior parts of this research. The two surveys (2 and 3) will be jointly referred to as 'the survey' in the following sections and chapters, unless specified otherwise. The design of the survey questions was driven by the Three-dimensional Energy Profile framework (the analytical framework) and focused on exploring end-users' experience with energy services, devices and carriers in the different domains: personal and contextual, as well as individual and shared. The mix of questions included predominantly close-ended questions and open-ended questions where an elaboration on the answer to a close-ended question was needed or deemed beneficial. The survey therefore allowed for collection of both quantitative and qualitative data, in line with

[12] *Imihigo* (performance targets) questions were added while Survey 2 was still ongoing, which will be discussed in section 4.1.2.5.

[13] In the process of data cleaning 1 interview was eliminated from further analysis as the interviewed customer was no longer using the SSHS, thus making it unsuitable for the study given its scope.

the broader study design. It also included questions on the socio-demographic profile of the respondents, such as age, gender, family size, and a standard set of Poverty Probability Index questions for Rwanda to assess respondents' poverty levels. Prior to commencing data collection with the use of the designed survey, Research Assistants conducted cognitive testing of the survey to ensure correct wording and clarity of questions (Fowler, 2014), and appropriate translation from English to Kinyarwanda. See Appendix 6 for the survey questionnaire (in both English and Kinyarwanda).

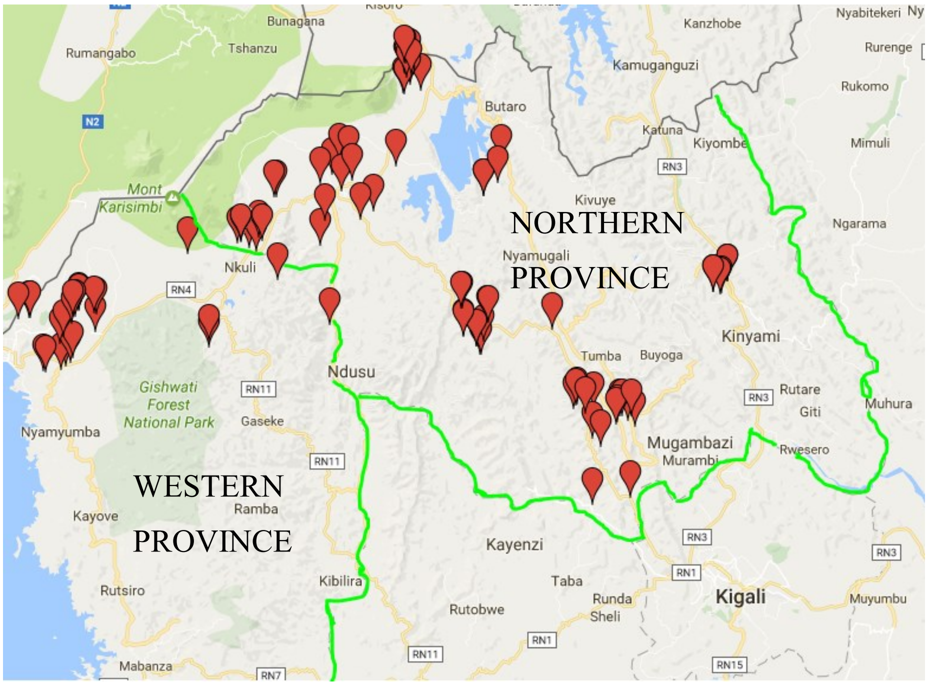


Figure 3.1. Location of the 97 in-household interviews (marked by pins).

Participatory photography was added to the methods as a result of winning a grant which allowed the researcher to conduct participatory photography workshops with 20 households across Rwanda (in all four provinces) where SSHSs have been adopted as a way of accessing energy. There has been a growing body of knowledge showing that visual methods, and in particular participatory photography, can offer valuable insights into the lived experiences of people and groups of people (households, communities, etc.) (Winton, 2016). It is seen as a useful tool for engaging people to present their view of the world (Alam et al., 2017) in a way that gives them the power to speak their own realities through image (Clover, 2006). Historically, photography has been used in research as a way of complementing the more traditional research methods (surveys, interviews, questionnaires, etc.). However, it has been criticised for creating inequity of power (photographer vs the photographed) and the objectification of the other. This has sparked the emergence of participatory photography which hands over that power to research subjects who, using cameras, document, analyse and make meaning of their experiences themselves (ibid.).

Field notes were taken during data collection (by both the researcher and the Research Assistants for triangulation purposes) and data analysis was being done at the same time as data collection and continued after all data collection activities had been completed. This allowed for an early and continuous identification and interpretation of any new, relevant themes (Engel & Schutt, 2014) which proved invaluable in continually revising and adapting the course of the research and research questions. The process was accompanied by frequent reflective sessions between the researcher and Research Assistants in order to discuss key emerging themes and observations as and when, or shortly after they took place.

Further details on data collection scheduling and field work can be found in section 3.1.2 and 3.1.3.

It has to be acknowledged that the researcher had to rely on Research Assistants due to the language barrier (the researcher's knowledge of the local language Kinyarwanda is limited and not sufficient to conduct interviews in it) for each data collection activity, which may have impacted on the quality of final data (mostly in a written text format). In order to make sure translation was adequate and up to standard, the Research Assistants had been trained on the research context and objectives prior to commencing data collection and were a part of knowledge building through active involvement rather than passive assistance (Temple & Edwards, 2002). To ensure high standard of collected data, they had also been trained on participatory approaches and best practices in conducting interviews and focus groups which enabled them to build rapport and trust with the study participants, thus helping collect high quality, reliable data.

3.1.2 Data collection schedule

Data collection took place between November 2015 and October 2017, with the most activities conducted over the course of 2016. It comprised of three telephone surveys (Survey 1 (S1), Survey 3 (S3), and Survey 4 (S4)), in-household interviews (S2), a total of 10 focus groups (FGs), stakeholder interviews (SIs), and participatory photography workshops (PPWs). The full breakdown of all data collection activities can be seen in the table below (Table 3.1. Data collection breakdown showing the field trips in a chronological order, activity timeframes, methods used and numbers and locations of study participants, as well as gender split in surveys and focus groups.), which includes details on precise timing, method used, who it was conducted by, location (see Appendix 12 for a map showing the location of BBOXX shops demarcating areas to which participants belong to) and number of participants, as well as the male vs female split of survey and focus group participants. S1 was conducted in early stages of the research and proved to be an exploratory exercise. It disproved the initial hypothesis on the correlation between remote monitoring and customer satisfaction and was used to think more broadly about the experiences and needs of SSHSs users, which then informed the final set of research questions. Those have changed over time, however, not as considerably as post-S1.

DATE	METHOD	CONDUCTED BY	NUMBER/LOCATION	FEMALE VS MALE
UK-BASED (SURVEY 1)				
20/11/15-11/12/15	Telephone survey (Survey 1) **(Quantitative)**	3 Enumerators (based in Rwanda)	126 North-West: Kabaya, Byangabo, Mahoko, Musanze, Gakenke, Kidaho, Ruli, Vunga, Gasiza, Kirambo	117 Male, 9 Female
FIELD TRIP 2 (FOCUS GROUPS 1, SURVEY 2, SURVEY 3)				
20/06/16-17/11/16	Stakeholder Interviews **(Qualitative)**	Researcher	13 FONERWA (SI1: Private Sector Specialist) GIZ/Energising Development (SI2 Adviser, SI3 Results-Based Financing Officer) MININFRA (SI4 Energy Division Manager, SI5 Renewable Energy Senior Engineer) GIZ (SI6 Coordinator One Mainstreaming & Advisor in the Rights Based Program, SI7 Gender Expert) MINALOC (SI8 Planning & Imihigo Specialist, SI9 Integrated Development Planning Specialist) EDCL/REG (SI10 Director of Primary and Social Energies Development) RGB (SI11 CEO) OAF (SI12 Innovation Team Member) EPD (SI13 Project Manager)	
12/07/15-13/07/16	Focus Groups 1 (1-5) **(Qualitative with some quantitative)**	Researcher + 2 Research Assistants	5 (Participants: 40) North-West: FG1- Nyarubuye FG2- Bigogwe FG3- Cyuve FG4- Nyagahinga FG5- Gakoro	29 Male, 11 Female FG1- 6 Male FG2- 7 Male, 5 Female FG3- 3 Male, 3 Female FG4- 9 Male FG5- 4 Male, 3 Female
29/07/16-02/09/16	Survey 2 (in-household interviews 1-97) **(Quantitative with some qualitative)**	2 Research Assistants	97 North-West: Kabaya, Byangabo, Mahoko, Musanze, Gakenke, Kidaho, Gasiza, Kirambo, Gicumbi	52 Male, 45 Female
04/09/16-29/09/16	Survey 3 (telephone interviews 1-168) **(Quantitative with some qualitative)**	2 Research Assistants	168 North-West: Kabaya, Byangabo, Mahoko, Musanze, Gakenke, Kidaho, Gasiza, Kirambo, Gicumbi, Ruli, Vunga	141 Male, 27 Female

FIELD TRIP 3 (FOCUS GROUPS 2)				
07/11/16-09/11/16	Focus Groups 2 (6-10) **(Qualitative)**	Researcher + 1 Research Assistant	5 (Participants: 30) North-West: FG6- Raba FG7- Gakoro FG8- Nyabigoma FG9- Karangara FG10- Terimbere/Gashungu	25 Male, 5 Female FG6- 7 Male FG7- 3 Male, 2 Female FG8- 5 Male FG9- 6 Male, 2 Female FG10- 4 Male, 1 Female
FIELD TRIP 4				
21/03/17-31/03/16	Participatory Photography Workshops **(Qualitative)**	Researcher + 1 Research Assistant	20 All provinces (North, West, South, East): PPW1+PPW2- Nyamata (E) PPW3+PPW4- Muhanga (S) PPW5+PPW6- Gakenke (N) PPW7+PPW8+PPW9- Musanze (N) PPW10+PPW11+PPW18- Kayonza (E) PPW12+PPW13+PPW14- Gicumbi (N) PPW15+PPW16+PPW17- Gasiza (N) PPW19+PPW20- Nyanza (S)	13 Male, 7 Female (Plus family members)
FIELD TRIP 5				
26/10/16-30/10/16	Survey 4 (telephone interviews) **(Quantitative)**	1 Call Centre Operator (BBOXX)	30 North-West: Kabaya, Byangabo, Mahoko, Musanze, Gakenke, Kidaho, Ruli, Vunga, Gasiza, Kirambo, Gicumbi	23 Male, 7 Female

Table 3.1. Data collection breakdown showing the field trips in a chronological order, activity timeframes, methods used and numbers and locations of study participants, as well as gender split in surveys and focus groups.

As shown above, data collection was a multi-step process. Figure 3.2 below demonstrates the various steps and processes from the time of research commencement until the last data collection activity (S4) and research conclusion. The researcher began the study with a pre-determined set of questions (decided in the course of preparing the study proposal which was then competing for funding and won). Literature review was the first step and continued over the entire course of the study, until the very end. S1 was designed according to the initial set of questions and first stages of literature review. As the original hypothesis was not supported, research questions got revised and the study proceeded accordingly. The process was an iterative one and data collection tools were designed taking into consideration findings from preceding activities and continuous reflections. The use of different tools allowed for data triangulation while also enabling gradual theory building over study duration and at the time of final, cumulative analysis which included findings from all collected data.

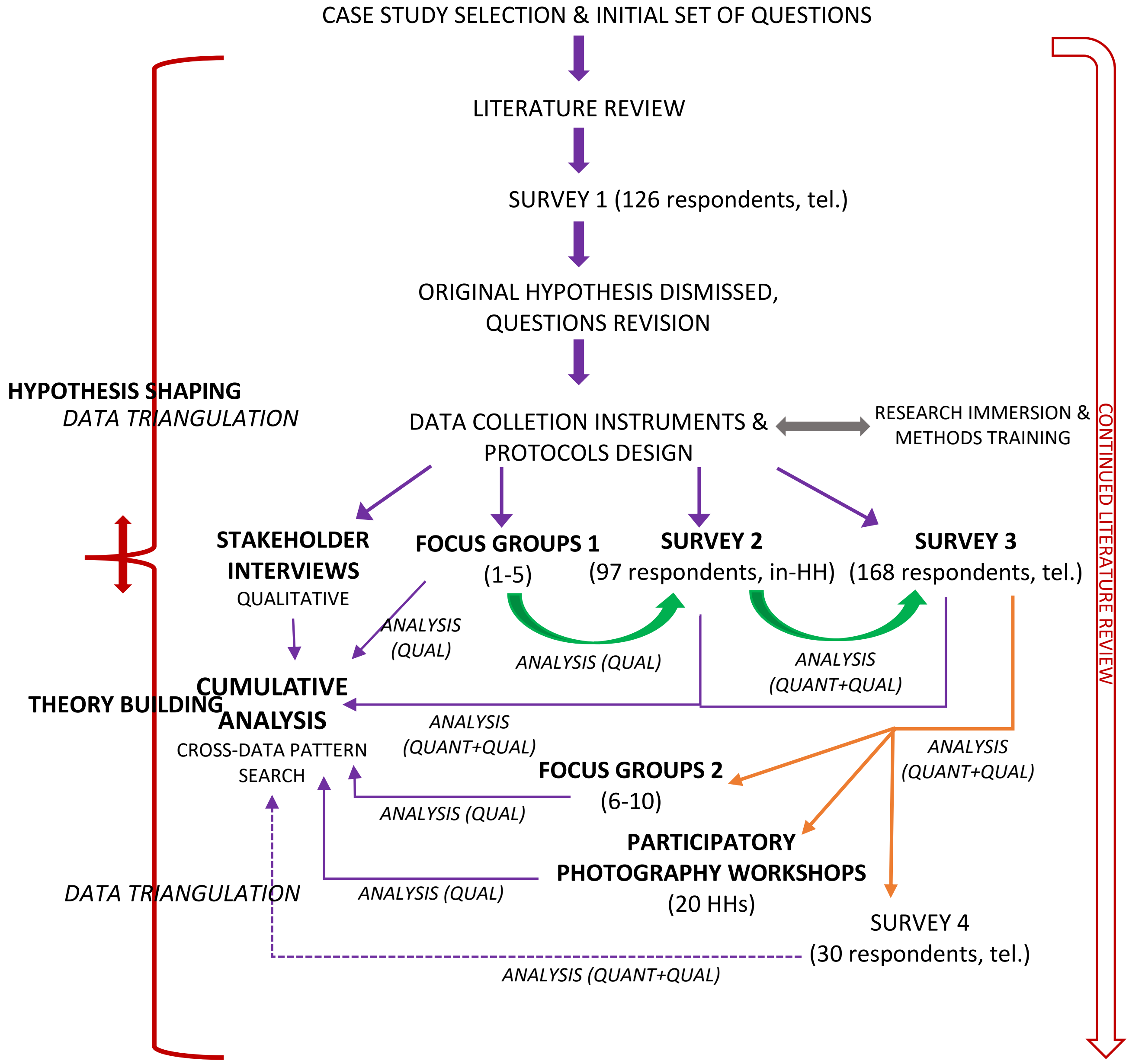


Figure 3.2. A flowchart demonstrating the research design and the chronological steps undertaken for data collection and tools design.

3.1.3 Field work

Over the course of this research, 5 field trips took place, each one with a different set of planned activities.

Field trip 1 (FT1) took place in early stages of the study (August 2015) and its aim was more exploratory. Other than visits to BBOXX shops and a few customers (in-household visits), as well as participation at marketing events which are organised frequently on market days in towns and villages in areas where BBOXX operate, the researcher did not collect any data. Field notes were the only tool used. FT1 was an opportunity to better understand the operations of the study partner and get acquainted with the local context. It proved invaluable for further work as the researcher gained insights into the local realities of SSHSs users who are at the heart of this study. FT1 gave the researcher an opportunity to establish contact with the UR-CST who agreed to affiliate this research for the purposes of obtaining a permit to conduct research in Rwanda.

Field trip 2 (FT2) took place between June and September 2016, and comprised of several activities, including three rounds of data collection aimed at SSHSs users, as well as stakeholder interviews (SIs) (which continued until the end of FT1 and into FT2).

Firstly, the researcher recruited two Research Assistants (RAs) according to their experience collecting and analysing data in a two-step interview process (practical and oral test). The researchers used several channels to advertise the two positions: the University of Rwanda as the local affiliating institution with access to graduates looking for employment and experience of building hands-on skills, the BBOXX recruitment channel and the word of mouth. All channels yielded at least 4-5 candidates. From the pool of over 20 candidates, 10 were selected for interviews and practical exams (focused on data analysis in Excel). After the initial round of interviews and the completion of practical tasks, three candidates were shortlisted for the final interview: two male and one female. Eventually, one male and one female assistant were selected, which was considered a good balance in order to make sure that the gender of the assistants does not impede on data collection (e.g. if only male assistants were selected, this could have precluded interviews with women who might prefer speaking with a female). Both RAs subsequently spent a week immersing themselves in reports and publications provided by the researcher on off-grid solar technologies, research which had been done on the subject to date and the aims and objectives of this study, as well as its background. The researcher made sure the RAs were well acquainted with the research scope and relevant other studies in this field before any data collection activities commenced. RAs then assisted with the preparation of tools including FG questions or more broadly themes determined by the questions and the analytical framework (see section 2.9), protocols, schedules and necessary translations. Employing multiple investigators, according to Pettigrew (1988), allows the case to be viewed from different perspectives and to capture divergent evidence. Similarly, having more than one investigator made it possible to visit multiple households at the same time, increasing time efficiency.

Secondly, 5 focus groups (FGs) were conducted with a total of 40 participants across the Northern and Western Provinces.

Overall, there are five Provinces which are divided into districts (which are further divided into sectors and sectors into cells):

- Eastern Province: Bugesera, Gatsibo, Kayonza, Kirehe, Ngoma, Nyagatare, Rwamagana
- City of Kigali: Gasabo, Kicukiro, Nyarugenge
- Northern Province: Burera, Gakenke, Gicumbi, Ruhengeri (Musanze), Rulindo
- Western Province: Karongi, Ngororero, Nyabihu, Nyamasheke, Rubavu (Gisenyi), Rusizi, Rutsiro

- Southern Province: Gisagara, Huye, Kamonyi, Muhanga, Nyamagabe, Nyanza, Nyaruguru, Ruhango.

Figure 3.3. The researcher (far back left) with two RAs conducting a focus group in Bigogwe (FG2), Northern Province. Photo credit: I. Bisaga.

FG discussions were recorded, with all participants being informed and giving consent, and notes were taken by the researcher and the RAs. After every FG the three discussed the key emerging themes and personal reflections, as well as revised the initial set of questions to adjust for any additional, particularly interesting ones (although no new themes were added to maintain consistency of collected data).

Once FGs were completed (mid-July 2016), the first findings analysis was used to inform the design of in-household interviews, which took place between the end of July and early September. The questions were coded onto Kobo Collect platform[14] enabling the use of tablets for data collection and the recording of precise location of interviewees, as well as photo taking (in instances were study participants agreed to have a photo taken). A total of 97 in-household interviews (for the purposes of this dissertation coded as Survey 2 – S2) were conducted (for locations, see Figure 3.1 in section 3.1.1). The number was dictated by the time and the resources available to the researcher. Even though the initial number of in-household interviews was set higher (at minimum 150, to ensure higher statistical significance of the sample), the encountered challenges prevented the researcher and the RAs from reaching that

[14] https://kf.kobotoolbox.org

number. Among them were: a) the remoteness of customers; b) the time and cost associated with reaching customers, particularly the remote ones; c) the availability of approached customers and challenges in scheduling (even though all interviews were arranged at least two days in advance, occasionally participants would not be at home or would request rescheduling to another day which proved very difficult); d) the inability of RAs to reach the expected number of customers per day as a result of far distances they had to travel between them and the overall time it would take to conduct one interview.

It is worth mentioning that while in-household interviews were on-going, stakeholder interviews (SIs) were taking place in parallel. The findings from SI6 and SI7 (conducted together) about household-level performance targets (*imihigo*) and the performance targets framework more generally (discussed in section 4.1.2) resulted in the addition of *imihigo*- focused questions to the interview schedule almost half-way through completing in-household interviews which meant that the first 39 interviewees were not asked those questions. Harris & Sutton (1986) advocate adjustments to data collection instruments, including adding questions to protocols in order to probe emergent themes. This has also been supported by Eisenhardt (1989) who claims that overlapping data collection and analyses (which was the case in this research) gives the advantage of flexible data collection and the ability to make changes to data collection processes, which she states is an important feature of case study research.

Upon completion of in-household interviews, continued data analysis informed the final design of telephone interviews (S3). The same platform (Kobo Collect) was used by the two RAs conducting the interviews, and the same set of questions as in in-household interviews was used, with a few additions (including the *imihigo* questions added earlier and a few more options in multiple-selection questions, to make data collection easier and achieve better data consistency, which then decreased the need for data cleaning). As the protocol was highly similar to that in in-household interviews, S3 contains interviews 98-265, indicating continuation of data collection utilising the same tool but conducted via telephone, rather than face-to-face.

FT 2 also saw the researcher obtaining the research permit from the Rwanda Ministry of Education and final affiliation with UR-CST.

FT3 was conducted in November 2016 by the researcher and one RA (one of the two who assisted with research design and data collection on FT1) and comprised of additional 5 FGs which were a follow up on FG1 and aimed to further explore some of the themes from S2, S3 and FG1 where clarifications were needed. FG1(5) and FG2(7) were conducted in the same village with some of the same community members. FT3 also included some additional SIs and the organisation of a seminar on off-grid solar energy in Rwanda (entitled 'Off-grid Solar in Rwanda: The Way Forward', see Appendix 15) with the participation of local stakeholders, including academics, practitioners, government representatives, donors and the wider public. It provided an opportunity to share some of the initial findings of this research, as well as obtain feedback from the seminar participants.

FT4 took place in March 2017 and was facilitated by a public engagement grant won by the researcher, which supported the 20 participatory photography workshops (PPWs) with 20 households where SSHSs have been adopted, in four out of Rwanda's five[15] provinces (Northern, Western, Southern and Eastern; moving away from focusing on the North-West of the country). PPWs were not initially included in the planned data collection as one of the tools to be used. However, the flexibility of changing and adding instruments when opportunities are present in a case study (Eisenhardt, 1989) encouraged the researcher to include them and their findings in the study, in particular given the richness of qualitative data which was collected in the process. The researcher and one RA visited 20 households over the course of two weeks. The workshops consisted of in-depth interviews around energy access and the impact SSHSs have had on the households, without a well-defined structure, allowing for a rich exploration of themes. Present household members would then be showed how to use the camera and given the freedom to spend as much time as needed taking photos which would reflect what had been discussed and whatever they felt demonstrated best the importance of having energy access, the changes, improvements, as well as challenges. Finally, the participants would take the

[15] The fifth province is the City of Kigali.

researchers through the photos they had taken and elaborate on their meanings and messages they were aiming to convey. Finally, participants were asked to share feedback on the experience, which was recorded on the Kobo Collect platform. Notes were otherwise taken by both researchers and after each PPW the two would discuss their observations and learnings, taking a note of each other's impressions.

Figure 3.4. A participant of PPW4 taking a photo of the cow the family purchased after switching to a SSHS. Photo credit: I. Bisaga.

FT5 took place in October 2017. Over a period of two weeks, 30 telephone interviews with 30 of the 265 participants of S2 and S3 to better understand some of the drivers of energy usage- questions which emerged after the initial analysis of results from S2 and S3.

For details on sampling for all the data collection activities in FT2, FT3, FT4 and FT5 see section 3.1.4.

Risk assessment was completed prior to each of the FTs and all efforts were made to ensure safety and security of the researcher, the RAs and the study participants at all times. No harmful incidents or accidents which would hurt any of the parties were experienced or reported over the course of conducting field work activities.

3.1.4 Sampling

For the purposes of this research and to answer the posed research questions, several sampling techniques have been used over the course of data collection.

For S1 (n=126) (95% CI, +/- 10%), simple random sampling from the entire customer base (the population) in Rwanda in November 2015 was applied. From among 180 sampled customers, 126 completed the telephone survey. The purpose was to test the hypothesis that remote monitoring impacts on customer satisfaction (which was not supported).

Having determined the research questions which would guide the rest of this study (and make up this thesis), the researcher became well-acquainted with the spread of the total population of users of SSHS (who were customers of the research partner) across Rwanda. Sampling for FT2 data collection first took place in April 2016 (when relevant sampling techniques were chosen) and June 2016 and used the numbers from those periods. It is important to stress that this study focused on 'active customers', meaning active paying customers using their systems so as to study customers using their systems (at the time of data collection), as the goal of this research is to understand those who use SSHSs on a daily basis. These customers, in BBOXX's database, figure as having a 'normal' status. Table 3.2 below shows the breakdown of all possible statuses:

STATUS	DEFINITION
normal	An active, paying customer; system on
late	Customer late with their payment (<15 days); system off
dlq	Delinquent customer, late with their payment (15-45 days); system off
default	Defaulted customer, late with their payment for >45 days; system off
repo	Repossessed customer; no longer owns the system

Table 3.2. Possible customer statuses (as per BBOXX's database).

Late and delinquent customers could still recover and resume paying thus regaining the ability to use their systems (hence they were still considered in the initial sampling steps undertaken in April 2016, as will be shown below). Defaulted customers would not be given that opportunity and would get repossessed. Therefore, the (late payment) grace period (allowing for payment recovery and resuming using the system) for customers is 45 days (under the business model valid at the time of data collection, for an outline showing the changing business models and system types please see Appendix 11).

The key factors (strata) determining the sampling process of SSHS users for this study were dictated by the research questions and the study location, and included:

A) Time since purchasing the SSHSs (with a minimum of 3 months since adoption; a shorter period was considered insufficient to allow for enough time to fully incorporate the system into daily routines and accumulate experience); to test whether the length of system use impacts on customer energy behaviour, needs and aspirations, customers were clustered into 3 groups:

GROUP	TIME SINCE SSHS PURCHASE
1	>12 months
2	6-12 months
3	<6 months (and minimum 3 months)

Table 3.3. Customer cluster groups according to time since SSHS purchase (i.e. length of use).

B) System type (BB Lights, BB Super Lights, BB TV, Ikaze and Aguka[16])

C) Customer gender (male/female)

As recorded at the end of April 2016, BBOXX had a total of 4367 customers (that includes late and delinquent ones who can still recover and gain the ‘normal’ status). Approximately 94% of all customers were male and 6% were female. The breakdown of customers according to the 3 Groups, gender and type of system (‘w/TV’ indicates those systems which include a TV as an appliance, which are the biggest system types, i.e. TV being the most energy-heavy appliance; these are the less frequently purchased systems) at the time of first sampling (April 2016) is shown in Table 3.4 below. N indicates the required representative sample size (95% CI, +/-10%):

GROUP 1			GROUP 2			GROUP 3		
Male	Female	w/TV	Male	Female	w/TV	Male	Female	w/TV
267	14	49	2158	188	230	1653	87	230
95%	5%	17%	92%	8%	10%	95%	5%	13%

[16] For a breakdown of various system types and accompanying appliances, please see Table 5.3 and Table 5.4 in section 5.1.3.4.

Total: 281	**n=72**	**Total: 2346**	**n= 92**	**Total: 1740**	**n= 91**

Table 3.4. Breakdown of customers in each Group of customers according to gender and system type as percentage of the total in the given Group.

Figure 3.5 below shows the number of participants split by Groups. The overall representative sample size for the entire population required was n=94 (95% CI, +/- 10%) with the final sample size of n=265 (S2+S3).

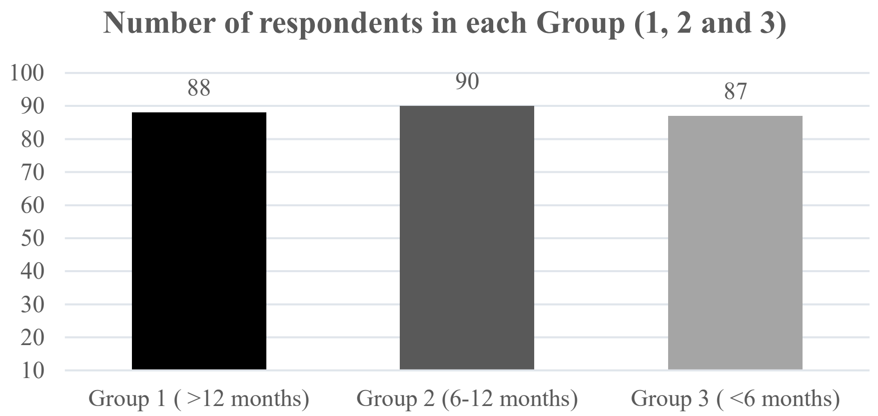


Figure 3.5. Number of survey participants (S2+S3) split by Group according to the length of time since system purchase (total n=265).

The most common system type was BB Lights and Ikaze (the basic systems with lights and mobile phone chargers, some also including radios). BB Super Lights are the least common (they are similar to BB Lights but include additional couple of lights, therefore they have been consolidated with BB Lights and Ikaze). BB TV and Aguka are the bigger system types and the most customers with TVs are among those system types (BB TV by default includes a TV, as the name indicates; Aguka does not always include one). For a detailed breakdown of system types among the SSHS users studied in this research please see Table 5.3 and Table 5.4 in section 5.1.3.4.

In June 2016, there were a total of 3357 'normal' customers. For the purposes of getting an even distribution across the Northern and Western provinces, the following clusters of customers according to their belonging to one of 11 shops[17] were utilised (Table 3.5):

SHOP (DISTRICT, PROVINCE)	NUMBER
Musanze (Ruhengeri, Northern)	336
Kirambo (Karongi, Western)	341
Vunga (Nyabihu, Western)	456

[17] A map showing the location of the shops can be found in Appendix 12.

Kabaya (Ngororero, Western)	357
Gakenke (Gakenke, Northern)	336
Byangabo (Ruhengeri, Northern)	231
Gasiza (Burera, Northern)	461
Kidaho (Burera, Northern)	220
Mahoko (Gisenyi, Western)	274
Ruli (Gakenke, Northern)	276
Gicumbi (Gicumbi, Northern)	0[18]
TOTAL Northern Province	**1860 (56.6%)**
TOTAL Western Province	**1428 (43.4%)**
TOTAL	**3288**

Table 3.5. 'Normal' customer clusters breakdown according to shop (and district) as of early June 2016.

Approximately 57% of all customers were in the Northern Province and 43% were in the Western Province (Figure 3.6).

Figure 3.6. Map demonstrating the distribution of customers (in %) across Northern and Western provinces in Rwanda as of early June 2016. Source: <http://www.geographicguide.com/africa-maps/rwanda.htm>

[18] The Gicumbi shop was opened later in June 2016 and there were no customers in the Gicumbi area at the time this breakdown was prepared, hence the '0'. Customers who subscribed later in June were then included in the sample of interviewed users (see Table 3.6), as they were located in the Northern Province and also because users in other areas were often hard to reach so including Gicumbi area customers allowed for a bigger sample. The total number of interviewed customers in Gicumbi was 15.

To conduct FG1(1-5), convenience and purposive sampling methods were adopted. Convenience sampling was necessary to ensure accessibility and availability of participants. Purposive sampling was then applied to ensure female participation in FGs (i.e. to achieve representativeness (Teddlie & Yu, 2007)). Between 10-15 SSHS users (allowing for attrition and aiming for the recommended number of between 4-8 participants per FG (Kitzinger, 2005)) in 5 relatively easily accessible villages across Rwanda's North-West were approached, making sure that both male and female users were invited to participate. Taking an average of 13 invitees per village (total of 65), the attendance rate achieved was 62%, with 28% of the total participants being female.

For S2, which entailed visiting customers in their households (in-HH interviews), first cluster sampling was applied. Clusters were determined by the belonging to a shop (as shown above). Subsequently, purposive stratified sampling was utilised in order to reach customers in different strata, namely: time Groups, both male and female (particularly given the small proportion of female system owners, which in April 2016 stood at approximately 6%, it was important to deliberately target that part of the entire population), and customers with different system types. Finally, convenience sampling was adopted for the purposes of selecting customers who were not too remote and therefore more accessible. The final sample size of n=97 achieved for S2 included customers from all shops other than Ruli and Vunga which proved to have customers too remote to reach.

For S3 (telephone interviews), first cluster sampling was applied. As in S2, clusters were determined by shop belonging. Secondly, random sampling from among all clusters was conducted. It was done with the use of excel and its random lists generation function, as is now commonly seen when a computer programme is used and the sampling involves a large number of units/individuals (Teddlie & Yu, 2007). As the number of customers in S3 was expected to be higher than in S2, random sampling was expected to yield a final sample of customers with a diversified set of characteristics, including those of particular interest in this research (the strata as mentioned in points A, B and C above). In the final sample of n=169 (out of which 1 was no longer using the system and was therefore disqualified from the sample considered for further study, effectively making the S3 n=168), various times of system use, and system types were represented. In terms of gender of research customers, a much smaller proportion of those reached were women, as compared to S2. That was the result of an overall much smaller female ownership of systems among all customers, as mentioned above. This was reflected when random sampling was applied. The n=168 was dictated by the time and resources available to the researcher (the two RAs conducted the interviews over the course of September 2016 with the goal of reaching as many customers as possible, ultimately arriving at the final number of 169 at the end of the month, with 168 valid response sets).

NUMBER OF PARTICIPATING CUSTOMERS PER SHOP (S2+S3)			
		Frequency	**Valid Percent**
Valid	Byangabo	25	9.4
	Ruli	21	7.9
	Vunga	25	9.4
	Gakenke	22	8.3
	Gasiza	30	11.3
	Gicumbi	15	5.7
	Kabaya	21	7.9
	Kidaho	32	12.1
	Kirambo	27	10.2
	Mahoko	27	10.2
	Musanze	20	7.5
	Total	**265**	**100.0**

Table 3.6. Cumulative number of participating customers per shop (S2+S3) (n=265).

For FG2(6-10), the same technique as for FG1(1-5) was applied, with an attempt to include some of the same participants as in FG1. That was possible only in the case of customers in Gakoro sector (FG1(5) and FG2(7) were conducted there, with 7 and 5 participants respectively, where the 5 participants in FG2(7) were also present in FG1(5)). FG2's main goal was to obtain clarification on some of the early findings from S2 and S3 and follow up with the customers on some of the themes which yielded particularly interesting results.

Convenience and purposive sampling techniques were adopted to identify customers (and their households) for PPWs who would be accessible (to save time and resources), and willing to participate. There was an attempt to include a diverse set of customers with various characteristics in the total (pre-determined) number of 20 households expected to participate, however, it was not followed rigorously. The final n=20 did include a range of different system types and customers using a SSHS for different lengths of time (including some who had been using the system for less than 3 months), as well as both men and women, often participating together as in 16 out of 20 visited households more than just one household member would take part (for the details of PPWs participants see Table 3.7 below). However, the sample is not big enough to be statistically significant and therefore no generalisations can be made based on it. Yet, given that qualitative research does not always aim to be representative of a wider population and is meant to provide a researcher with a basis for developing themes from emerging data (as is also the case with focus groups) and constructivist knowledge claims (Creswell, 2003), which the data collected from the 20 PPWs did offer, the findings were seen as valuable and useful for theory building and ultimately fitted the mixed method approach of this study.

PPW Number	**SSHS Package**	**Home/Business**	**Length of Use**	**Gender (owner)**	**Participating**
PPW1	Aguka	Home	7 months (Group 2)	Male	Wife with children
PPW2	Ikaze	Home	8 months (Group 2)	Male	Owner with wife
PPW3	Aguka (+TV, torch, radio)	Home	11 months (Group 2)	Male	Wife
PPW4	Aguka	Home	11 months (Group 2)	Female	Owner with children and grand-children
PPW5	Ikaze	Home	2 months (Group 3)	Male	Owner with wife and children
PPW6	Aguka (+radio)	Home	1 year (Group 1)	Male	Wife with children
PPW7	Ikaze (+TV)	Home	11 months (Group 2)	Male	Wife with children
PPW8	BB TV (+radio)	Home/Business (ran from home)	1 year 4 months (Group 1)	Male	Owner with children and co-workers
PPW9	BB Lights (+radio)	Home	9 months (Group 2)	Male	Owner with wife and children
PPW10	Aguka	Home	3 months (Group 3)	Female	Owner

PPW11	Aguka (+TV)	Home	3 months (Group 3)	Male	Wife with children
PPW12	Aguka (+TV)	Business	8 months (Group 2)	Male	Owner with friends
PPW13	Ikaze	Home	6 months (Group 3)	Female	Owner with children
PPW14	Ikaze	Home	5 months (Group 3)	Male	Owner with wife
PPW15	Ikaze (+TV, radio)	Home	9 months (Group 2)	Male	Owner with children
PPW16	BB Lights (+radio)	Home	6 months (Group 3)	Male	Owner with wife
PPW17	Aguka (+radio)	Home	2 years (Group 1)	Male	Owner with wife and children
PPW18	Ikaze	Home	7 months (Group 2)	Male	Owner
PPW19	Aguka (+TV, radio) & Aguka	Home	1 week (Group 3)	Male	Wife with children
PPW20	Ikaze	Home	2 months (Group 3)	Female	Owner

Table 3.7. Details of PPWs participants, including system package, length of use (time since system adoption), gender of the owner and who participated in the workshop (owner not always present at the time).

Having analysed energy usage data from S2, S3 and from the SMART Solar platform, questions related to energy usage levels among different Groups emerged and S4 was designed as an additional data collection tool to obtain further insights into that component of the study. A telephone survey with 30 customers (10 from each of the three Groups (1, 2 & 3), selected only from among 'normal' status customers at the time of conducting the survey, i.e. September 2017) was conducted using two enumerators. Sampling, therefore, was done from among the pool of n=265 (combined S2 and S3). 'Normal' customers from each Group were identified after which randomisation (using Excel) was done. It is important to stress that at the time of S4, 145 of customers (out of the total n=265) had a 'normal' status. Calls were made using the generated lists and enumerators continued to call customers from each of the Groups until they reached a total of 10 per each group. N=30 was achieved over the course of 5 days which was the time enumerators were available to conduct the calls. This sample size is not statistically significant, and no generalisations can be made based on it. The findings from S4 have shown results which did not fully offer the sought clarifications and have therefore not contributed to the study in a significant way but rather as a validation of previous findings.

Over the course of sample selection at all stages of this study, only the researcher and the 2 RAs had access to personally identifiable information of the participants. In final datasets, however, all names have been erased and only customer ID numbers (as assigned in BBOXX's database) were visible. Participants could not be identified by those unless the person accessing the data would also have access to BBOXX's database. No personally identified information has been used in this thesis and all names have been coded.

3.1.5 Data analysis

Quantitative data, including that from surveys and from remote monitoring of SSHSs via SMART Solar have been analysed using statistical packages in Excel and SPSS. SMART Solar data basic analysis was done as data was being collected in order to monitor for any emerging patterns and the need for any follow up. It then continued after data collection was completed.

Qualitative data has also been analysed in an iterative and reflexive manner so as to allow analysis while data was being collected rather than exclusively after the collection has ceased. It then continued post data collection. This enabled the researcher to constantly interpret and explore the rich findings (Stake, 1995). A general inductive analysis approach was assumed, allowing research findings to emerge from the dominant themes and categories intrinsic in the raw data (Thomas, 2006). Extensive raw data were condensed into summaries and links were established between summary findings and the research questions, which enabled an iterative development of theories and models of the underlying structure of energy use experiences pertinent to the adopters of off-grid SSHSs (ibid.). Additionally, a qualitative data analysis programme NVivo was utilised. NVivo was selected as a tool available through the University College London and one that is easy to navigate, while offering a very good functionality, satisfying all the needs of qualitative data analysis within this research. Notes and transcripts from SIs, FGs and PPWs, as well as photographs from PPWs and some qualitative insights from S2 and S3 were analysed and categorised using nodes, each one representing a different theme (or sub-theme), and relationships to map out the network of links across the identified themes, as described above is common in the general inductive analysis logic. These thematic categories were the nested under the analytical categories, which were extracted from the analytical framework (for details of the analytical framework see section 2.9). Adjacent (child) nodes were also created to cover the breadth and depth of the thematic categories (for qualitative analysis codebook, project map and nodes relationships, and nodes structure, see Appendix 7, Appendix 8 and Appendix 9). This process of coding data (which also included coding of individual participants details for the purposes of preserving anonymity), served three different functions, as outlined by Bernard & Ryan (2010: 87): encryption; a tool for indexing and tagging data (text and images); and a value code to demonstrate the frequency of a particular theme or characteristic. Qualitative text analysis was mainly guided by the work of Kuckartz (2014), Flick (2014) and Thomas (2006).

3.1.6 Coding

Coding for qualitative data has been designed as following:

FG1 – Focus Groups 1 (1-5)
FG2 – Focus Groups 2 (6-10)
S1 – Survey 1 (telephone interviews, 1-126)
S2 – Survey 2 (in-household interviews, 1-97)
S3 – Survey 3 (telephone interviews, 98-265)
S4 – Survey 4 (telephone interviews, 1-30)
SI – Stakeholder Interview (1-13)
PPW – Participatory Photography Workshops (1-20)

Survey 2 and Survey 3 jointly referred to as ‘the Survey/the survey’ unless otherwise specified.

In referring to a specific interview or focus group, codes have been used in the following manner:

e.g. FG1(3) – Focus groups 1 (first round), focus group 3

SI12 – Stakeholder interview 12

S2(45) – Survey 2, respondent 45

To designate 3 poverty groups (under $2.50/day 2005PPP) as determined by the Poverty Probability Index (PPI), the following codes have been used:

LLP – low likelihood of being poor

ILP – intermediate likelihood of being poor

HLP – high likelihood of being poor

To designate 3 Groups (referred to in the text as 'Groups' or individually as 'Group') of customers using their systems for different time periods:

Group 1: >12 months

Group 2: 6-12 months

Group 3: <6 months

Respondents' quotes are coded with: gender, survey/FG/PPW indicator, place: e.g. (Male participant, FG1(3), Cyuve).

3.2 Interdisciplinarity

As this research study has drawn on literature and evidence from both the development field (and particularly energy for development), sociology and social anthropology, an interdisciplinary approach to analysis has been adopted. Interdisciplinary research involves the use of conceptual models integrating or linking theory from two or more disciplines (Aboelela et al., 2007). According to Repko (2008: 217), it is important to "analyse the problem from the perspective of each relevant discipline, and evaluate each relevant insight into the problem, identifying strengths and weaknesses." This is of key importance as in this kind of research each discipline makes only a partial contribution to the integrated whole (ibid.). In order to explore the subject fully, reference to both disciplines is made where appropriate, throughout the study.

3.3 Pragmatism

Pragmatism stems from the work of several scholars, among them Peirce, James, Mead, Dewey and more recently Patton and Cherryholmes (Creswell, 2003). Despite the many forms pragmatism takes, for the majority of them knowledge claims derive from situations, actions and consequences rather than anterior conditions, which is the case in post positivism (ibid.). As argued by proponents of the pragmatic approach, instead of methods being the main study focus, it is the problem that is the most important and the researcher resorts to any methods necessary to explore and understand the problem (e.g. Cherryholmes, 1992; Patton, 1990). Teddlie & Tashakkori (2008) and Patton (1990) stress the significance of focusing on the research problem, particularly in social science research, and the application of pluralistic approaches to extract knowledge on the problem under investigation, which makes up the philosophical underpinning of mixed research methods. Based on the various perspectives put forward on pragmatism, Creswell (2003: 12) interprets it to be: a) uncommitted to any one particular system of philosophy and reality; b) an enabler of researcher's freedom of choice of methods and procedures according to the research needs; c) a way of seeing the world not as an absolute unity but a complex phenomenon requiring complex (mixed) methods of investigation; d) proposing that truth is "what works at the time", with the mind and reality being intertwined rather than independent of each other; and e) an expression of the researcher's belief that research always takes place in "[…] social, historical, political and other contexts". As concluded by Creswell (2003), for a researcher adopting a mixed methods approach, pragmatism opens the door to not only several methods and different worldviews, but also various assumptions, forms of data collection and analysis. This case study, in its design and knowledge building, has taken a pragmatic stance and has utilised mixed methods to focus on the research problem, which is outlined in the research questions. Research steps necessary to explore the problem as fully as possible, within the existing limitations, discussed in section 7.4, have been taken by the researcher whose beliefs are aligned with those advanced by the pragmatist movement. The study has therefore not adhered to one single theory, accepted reality or antecedent condition, but has relied on the concept of complex realities in its attempt to build knowledge, and thus new theories, around the subject of this enquiry.

3.4 Ethical considerations

This section briefly discusses the ethical guidelines that have been used. To conduct an ethically sound research, standards outlined by the British Educational Research Association (BERA) in "Ethical Guidelines for Educational Research" (2011) have been adhered to at all times. Ethical approval for all components of the study was obtained from the UCL Research Ethics Committee (under Ethics Application 7445/002 and 7445/003) (Appendix 13).

All study participants, i.e. SSHSs users (BBOXX customers), as well as other stakeholders who contributed to this research (i.e. government representatives, development partners, and other energy sector representatives in Rwanda), were asked for a voluntary informed consent to take part in research activities, including interviews, surveys and focus groups. The researcher was always open and clear about the aim of the study and disclosed all the information about it to the participants, who retained the right to withdraw at any point in the course of this research (none of those approached did). Anonymity was ensured to all participants and their names are not disclosed but instead have been coded as is the standard practice. In all databases containing participants' responses, names have been replaced by customer ID numbers for surveys (e.g. RWANDAMUSANZE123) and tool codes for FGs and PPWs (e.g. Male participant, PPW13), as demonstrated in section 3.1.6. Identification of participants' names was only possible with full access to BBOXX's CRM which the researcher did have but the RAs did not. At no point was such identification necessary. A separate consent form (designed according to the guidelines provided by UCL Ethics Committee) was used in the participatory photography workshops where participants were informed that photos from the workshops could be used for research purposes and appear in the research outputs (e.g. dissertation, photo exhibition). They were explicitly given the option of either appearing or not appearing in the photos and were also free to withdraw at any time. The visual materials produced in the course of this research have not been used for any purposes considered unethical or otherwise not mentioned to the participants in the consent form (e.g. advertising). No workshop participants withdrew from the research due to the production of visual materials (at the time of the workshops as well as in the time afterward).

As this research did not include children or vulnerable groups, no special arrangements and ethical clearance for work with such groups was required. To the best of the researcher's knowledge, this research has caused no harm to its participants. All possible efforts were made to mitigate any negative impacts that may occur during conducting a research study (such as emotional distress or intimidation).

Any responsibilities to the sponsors of this research (i.e. BBOXX and UCL), as stated in the research contract signed by all parties prior to commencing this study, have been obeyed. Publication of findings (in the form of journal publications and this dissertation) has been carefully considered throughout the study's duration. All findings have been fully disclosed to the sponsors and consulted on prior to making them available to the public.

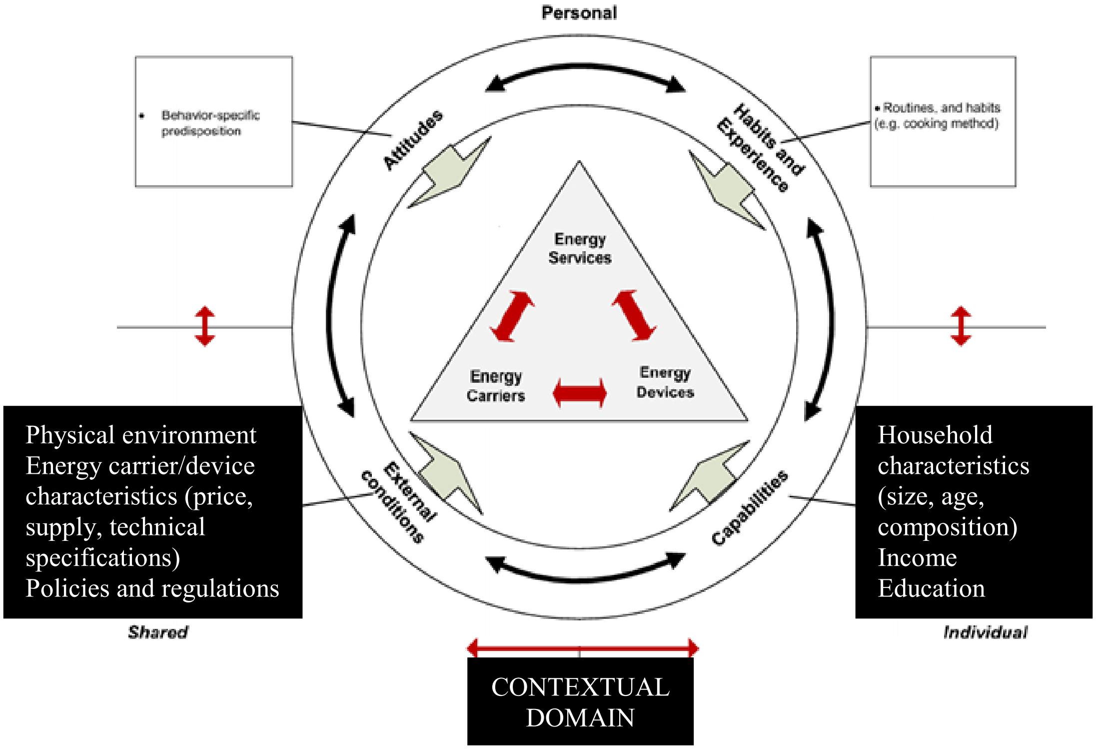
As this research took place in Rwanda, local ethical guidelines have also been followed. The study has been affiliated with the University of Rwanda – College of Science and Technology (UR-CST) and local ethical and research approvals have been obtained through the University and the Ministry of Education (under Permit No: MINEDUC/S&T/379/2016). For research and ethics approvals, please see Appendix 13.

3.5 Positionality and reflexivity

Sultana (2016: 374) argues that it is important to "[…] pay greater attention to issues of reflexivity, positionality and power relations in the field in order to undertake ethical and participatory research." Personal differences, including researcher's and participants' backgrounds, inequalities and political context all play a role in the interactions between the one researching and the ones being researched or researching with (ibid.). In this study, the researcher was a European female and therefore an outsider to the context in which the study took place. Being a stranger physically as well as culturally meant that the researcher had to be particularly aware of the politics of knowledge production as well as being reflexive on self, representation and the process of conducting research. Power relations had to be critically examined in order not to overstep, at any point in the course of the research, the boundaries allowed in the local context. The researcher's positionality needs to therefore be acknowledged and has influenced methods used, interpretations of data collected and the produced knowledge as she inevitable brought in her specific background, perceptions and predispositions, as well as ‘ways’ of doing things into the research and its design. The assistance of the two RAs, who were local and therefore considered to be insiders by study participants, even if coming from the position of power (the ones asking questions rather than being asked), helped the researcher in the commitment to conduct an ethically sound and culturally-sensitive study while at the same time acknowledging her positionality and subjectivity. Time spent in the field additionally made the researcher more aware of the acceptable and expected ways of behaviour and the appropriate etiquette. The researcher was not the one leading the interactions in FGs and interviews (other than in stakeholder interviews), with the two RAs taking the lead instead so as to get the community buy-in more easily. The presence of the researcher was not usually considered problematic or impacting on the objectivity of the participants, however, on a couple of occasions the researcher did step out from the FGs to allow a discussion free of the clearly observed difference between the researcher, the RAs and the participants. These instances were also reflected on and discussed with the RAs who were able to distinguish when the researcher’s presence had an impact on the participants and when it did not. Reflexivity was also expected of the RAs with whom debriefs on issues of positionality and reflexivity, as well as power relations, were frequently conducted throughout the process of data collection. The dynamic of power relations was additionally influenced by the perceptions of the participants, some of whom believed that both the researcher and the RAs had the power to make changes to the ways BBOXX operate despite making it clear at the start of each FG, PPW and interview that none of the three were BBOXX employees and were unable to make such decisions. Instead, it was communicated to the participants that findings from the research would be shared with the provider and could influence future decisions related to the product and the service. The researcher’s work being in close proximity to the local BBOXX team in Rwanda meant that there might have been a level of biased introduced to the study (whether at the stage of design and research questions determination, data collection and/or interpretation) that has to be acknowledged. In addition to describing an individual’s world-view and his/her social reality (the ontological assumptions), positionality also means the position the researcher has adopted, through a deliberate choice, in relation to a specific research task within a given research subject (Savin-Baden and Howell Major, 2013). It is identified in relation to the subject itself, as well as the participants, the research process and the research context (ibid.). As posited by Foote and Bartell (2011: 46) "[…] the positionality that researchers bring to their work, and the personal experiences through which positionality is shaped, may influence what researchers may bring to research encounters, their choice of processes, and their interpretation of outcomes." Sikes (2004: 15) further argue that "[…] it is important for all researchers to spend some time thinking about how they are paradigmatically and philosophically positioned and for them to be aware of how their positioning- and the fundamental assumptions they hold- might influence their research related thinking and practice. […] being a reflective and reflexive and, therefore, rigorous researcher […] is important given that a major criticism of much educational research is that it is biased and partisan." Particularly in a case of this type, where research is conducted in collaboration with a partner organisation, researcher's positionality may therefore have influenced the research design, the choice of questions and also the choice of research subjects in a way that would have been more aligned with the industrial partner's agenda. Choosing to focus on 'normal' customers, i.e. customers using SHSs and actively paying for them (rather than defaulted or repossessed customers) was driven by the research design focusing on the 'users of SHSs in Rwanda' (to examine the current experience and reality), however, this particular type of customers might be, by nature of their status, the less critical ones of the business model and services provided by BBOXX as compared to those who have had their systems repossessed due to ceasing payments, for example. That choice process have been impacted by the context of this study and might have also influenced the way the questions were posed and results interpreted, effectively making the researcher assume a less critical approach, despite a level of critique being present throughout the duration of this study and this thesis. These issues related to positionality are especially prevalent in qualitative research (Savin-Baden and Howell Major, 2013), which this study has a strong component of.

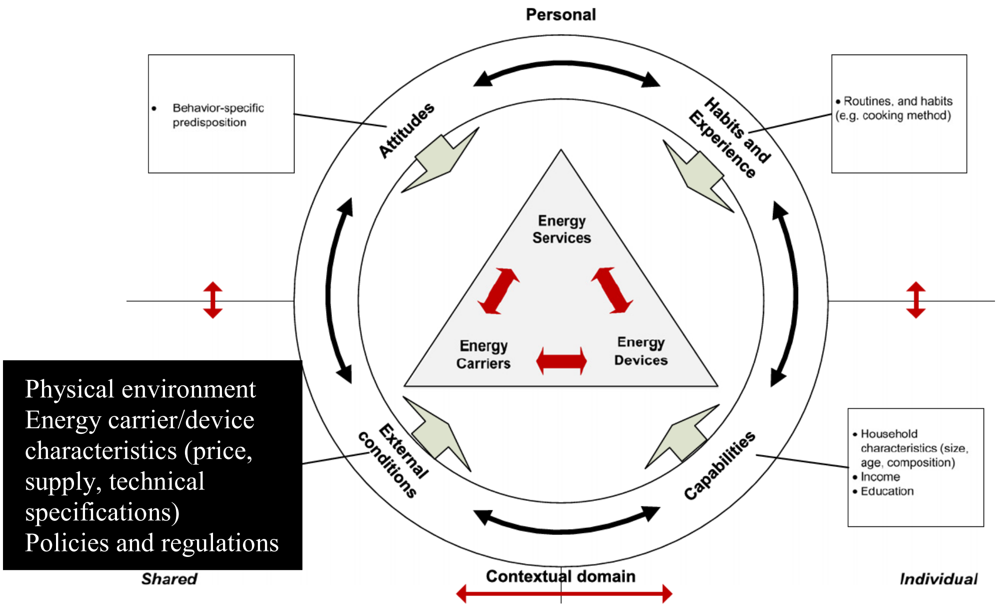
Yet it is necessary for the researcher to disclose and acknowledge her own positionality, and the decision to conduct research in collaboration with an industrial partner with a mission to provide energy access in off-grid areas, which is one the researcher supports, even if not uncritically. The partnership with BBOXX has, on the one hand, allowed for a deep exploration of the experiences of rural households adopting off-grid solar energy, and, on the other hand, positioned the researcher in a way more prone to bias and partisanship. Efforts were made to create sufficient distance and retain both reflexivity and objectivity in the researcher's approach so as to present a reality devoid of bias to the highest extent possible. This has been recognised as one of the study limitations and is further discussed in section 7.4.

Chapter 4 Findings: Contextual Domain



The contextual domain sets the scene for where the study was conducted and what the key participating household characteristics are. It consists of external conditions and household capabilities. The former, which are independent of the participating households, includes factors such as the physical environment, energy carrier and device characteristics, and the policy and regulatory environment. The latter, which focuses on the socio-economic profile of the participating households and is dependent on the HH members, demonstrates HH composition, size, age, income, education and more, to further reveal the profiles of those who have been the primary focus of this study, i.e. the users of SSHSs in North-Western Rwanda.

4.1 External conditions



Section 1.3 gives a brief overview of the study location, outlining the key country indicators and policies. The following sections will present a more detailed description of the wider context in which this study took place, focussing on the external conditions as demarcated in the analytical framework.

4.1.1 Physical environment

Rwanda is one of the smallest countries on the African continent. It is landlocked and densely populated, giving home to 11.9 million people (2016 estimate) on 26,338km². It is situated just under the equator and is commonly known as 'the land of a thousand hills' due to its hilly landscape. It hosts the Virunga National Park with five volcanoes in the North-West, sharing it with Uganda (to the North) and DRC (to the West), two of its four neighbours (the other two are Burundi to the South and Tanzania to the East). It has 23 lakes, among which the methane Lake Kivu is the biggest one (shared with DRC). There are numerous rivers, some of which form the source of River Nile. The climate is temperate throughout the year, with two rainy (Feb-June, Sept-Dec) and two dry seasons (June-Sept, Dec-Feb). High elevation of the country (1,500-2,500m, going up to 4,500m in the volcanoes region) makes for slightly lower temperatures than in other equatorial climates, placing them in the range of 15-27º C, with little variation throughout the year. Mountains dominate Northern, Western and parts of

Southern Rwanda, rolling hills in the centre, while the Eastern part is flatter, with savannas, swamps and plains (see Figure 4.1 below). The vastly challenging topography of the country makes it difficult to extend services such as electricity, water or sanitation to many areas, particularly the remote, rural ones.

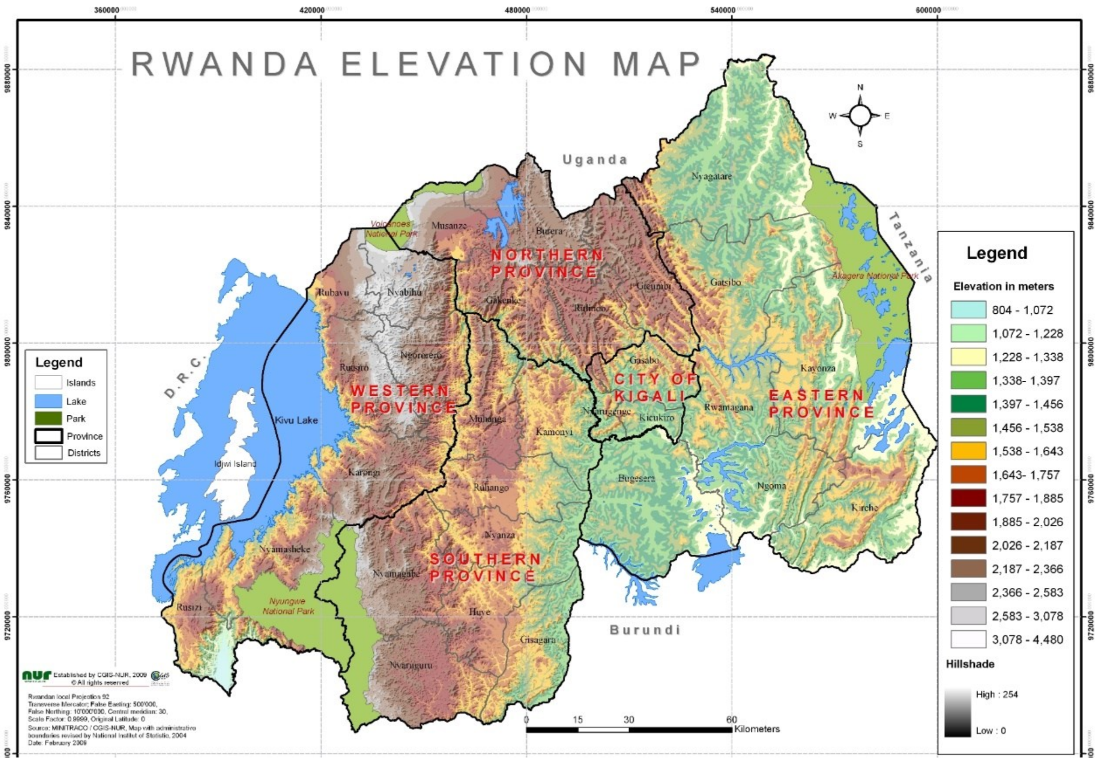


Figure 4.1. Map of Rwanda demonstrating the topography of the country, as well as its five Provinces. Source: University of Rwanda (2014) at <http://cgis.ur.ac.rw/content/rwanda-elevation-map>

The study area spanned across Northern and Western Provinces, with study participants residing in all five districts of the Northern Province, and four districts of the Western Province. That region is not only the most mountainous one, but also one which gets less yearly irradiation as compared to other parts of the country, as shown on the map below (Figure 4.2).

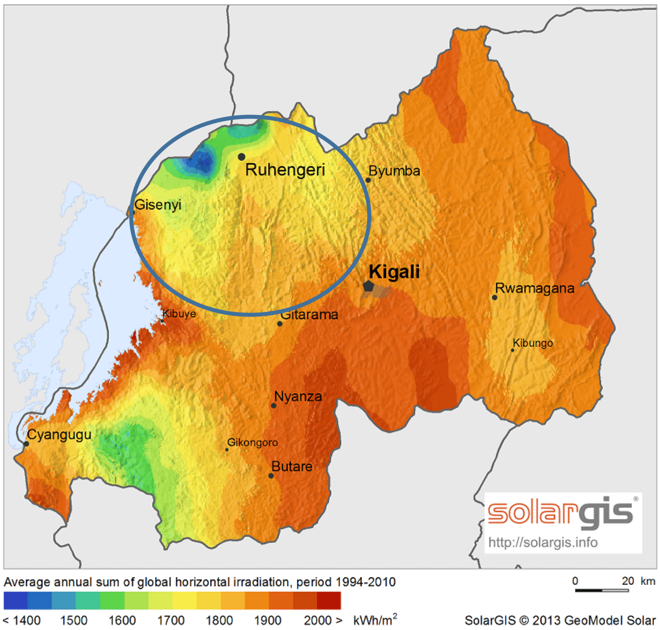


Figure 4.2. Average annual solar irradiation in Rwanda between 1994 and 2010. Circle marks the North-Western region. Source: SolarGIS at <https://www.africa-eu-renewables.org/market-information/rwanda/renewable-energy-potential/>

There are on average more overcast days in the North-West than in central, Southern and Eastern parts. This is significant for solar technologies which rely on sunshine for proper functioning and can impact on the reliability and consistency of energy services among users of SHSs.

GIS data was collected for the 97 HHs who participated in S2. On average, they were situated 1961.5m above sea level (s=312.285, median=1971.4m). The range spanned from the minimum of 159.3m to the maximum of 2713.3m. They were in relative proximity to the roads which was taken into consideration while performing purposive sampling aimed at selecting customers who would be reachable within a reasonable amount of time and at a reasonable cost. Their locations can be seen on the map below (Figure 4.3. S2 participants (n=97) location data overlaid on Google maps. A closer snapshot of the area in the lower image.).

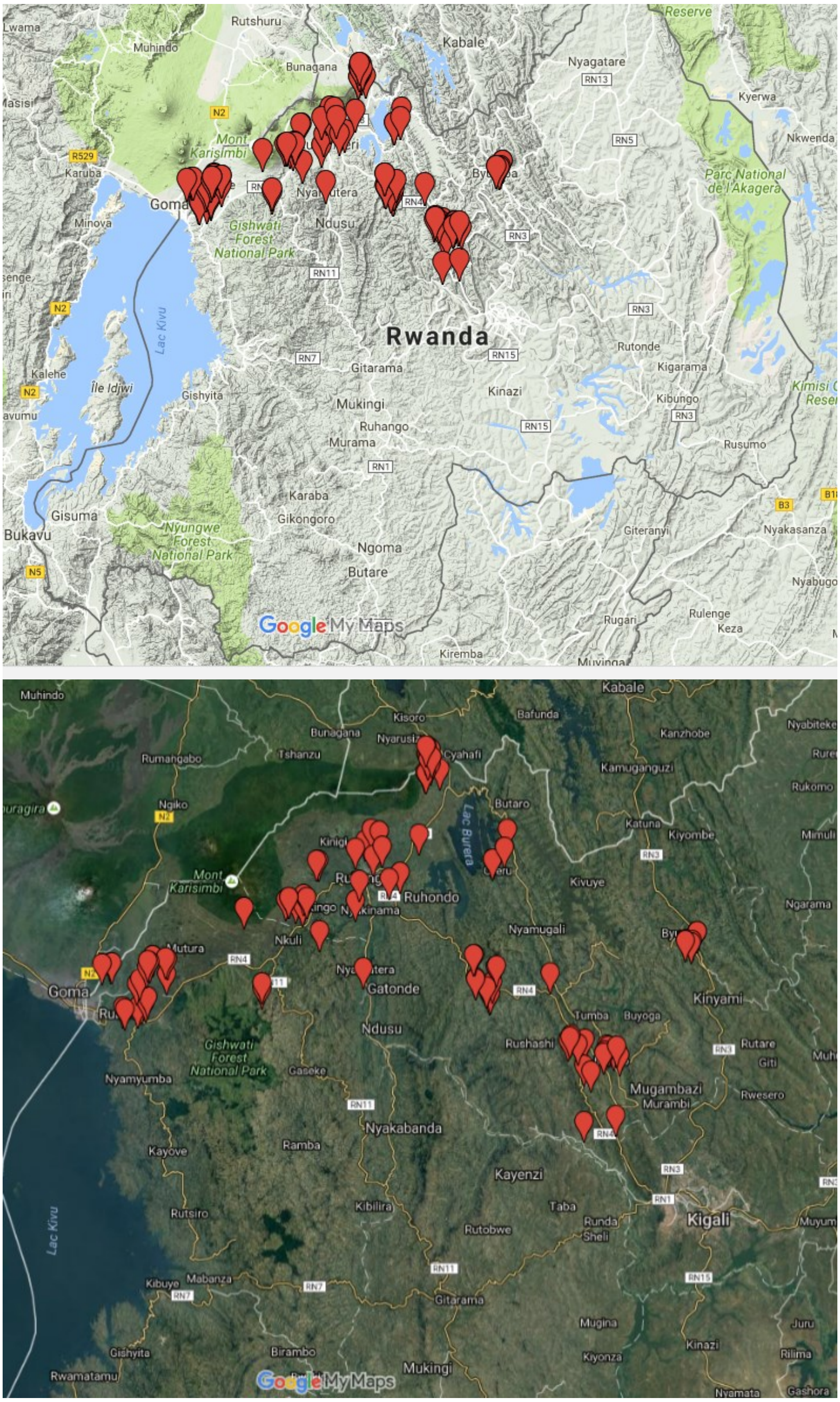


Figure 4.3. S2 participants (n=97) location data overlaid on Google maps. A closer snapshot of the area in the lower image.

The remaining HHs participating in the S3 were selected from the same region, however, they tended to be more remote as interviews were conducted over the phone and reachability was not a factor in the sampling process. FG1(1-5) and FG2(6-10) participants were also located in the Northern and Western Provinces, within approximately 30km radius from Ruhengeri (Musanze). PPW(1-20) HHs were selected from three Provinces (Northern- 11 HHs, Eastern- 5 HHs, and Southern- 4 HHs), with noticeable differences in the local topography across the North vs the South and the East (i.e. flatter terrain in the latter two as opposed to mountainous terrain in the former two).

Figure 4.4. 'Typical' landscape of the Northern Province. Gakenke, Northern Province. Photo credit: I. Bisaga.

The above figure (Figure 4.4) and below image (Figure 4.5) capture the landscape and the typical vegetation of that region of Rwanda. Many houses are located on hill slopes (like the one in the image above) which poses a risk of landslide damages in the rainy season. Corrugated iron is predominantly used for roofing[19], according to the current standards and requirements. Occasionally, clay tiles or shingles are used. Economy in roofing often causes water damage on the structure of the houses which are generally constructed of adobe blocks with 2-4 windows, 2 doors (entryways). Kitchens and

[19] In the last decade, the GoR undertook a nation-wide initiative to have all grass thatched roofs replaced with metal sheets (at least), or other improved materials.

latrines are usually separate from the main house (as shown in Figure 4.6 below). The orientation of a house generally prioritises the road over the sun and ventilation.

Figure 4.5. The hilly landscape and overcast days are common in the North-West. Gasiza, Northern Province. Photo Credit: I. Bisaga.

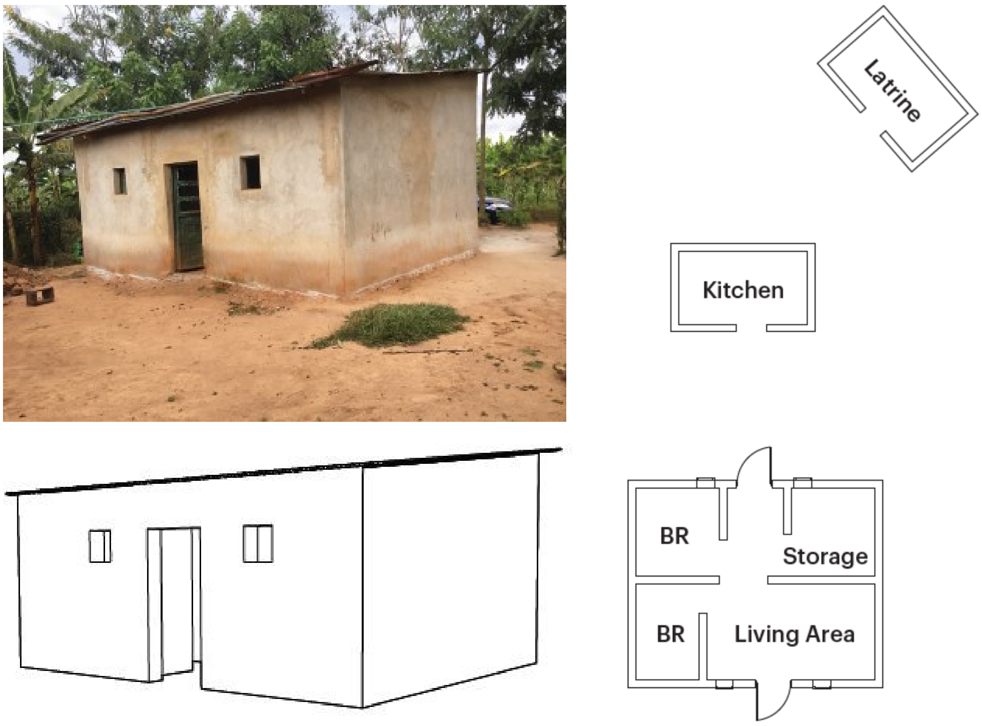


Figure 4.6. A "typical" rural house example. BR stands for bedroom. Water damage on the bottom of the house is visible (approx. 1m off the ground). Source and credit: BBOXX.

4.1.2 Energy policy, frameworks and regulations

This section consists of an abridged version of the researcher's article published in WIREs Energy and Environment (June 2018):

Bisaga, I., Parikh, P., Mulugetta, Y., and Hailu, Y. (2018). The potential of performance targets (*imihigo*) as drivers of energy planning and extending access to off-grid energy in rural Rwanda. *WIREs Energy Environ;* e310.

It outlines the policy and the regulatory environment in Rwanda, particularly focusing on the energy sector while also setting it in the context of the wider development strategy. It discusses the concept of *imihigo* which translates into performance targets. They are currently utilised as a framework for achieving development goals at all administrative levels, including the HH, and encompass energy access among other priorities.

Since the writing of the publication, there has been an update to the energy access targets which is noted accordingly.

4.1.2.1 Background

This paper introduces Rwanda's *imihigo* (performance contracts) which could act as a tool addressing questions of participation for energy policy making as well as for business model design among off-grid providers, and awareness-raising about off-grid energy thus contributing to demand activation and speeding up of electrification efforts. By examining how *imihigo* and, in particular, energy *imihigo* at various administrative levels impact on the adoption of off-grid solar systems, it argues that the *imihigo* framework could additionally be used to enhance the GoR's and the private sector's energy access efforts, offering more targeted and tailored off-grid electrification planning and provision. By investigating the challenges associated with the practical application and functioning of the *imihigo,* this paper also highlights what lessons can be learnt from it and how they can inform similar frameworks in other contexts. It draws on field research conducted in North-Western Rwanda between July and November 2016 with users of SSHSs.

4.1.2.2 Imihigo (performance contracts)

Since 2001, local levels of government have been responsible for the implementation of development programmes as a result of Rwanda's decentralisation. This shift created the need to strengthen accountability mechanisms towards the central government and towards all the citizens. *Imihigo,* known as performance contracts in English, were introduced in 2006 to address that need. The word *imihigo* derives from Kinyarwanda verb *guhiga* and means competition and self-commitment to achieve (Graham et al., 2010). In its singular, *umuhigo*, it signifies a vow to deliver. The concept stems from the pre-colonial cultural practice of individuals setting themselves targets for a specific period of time (Rwandapedia, 2016) and is one of Rwanda's Home-Grown Solutions (HGSs) (Shyaka et al., 2016). Performance contracts are signed every year between the President, the Ministries and local government institutions, binding all signatories to achieve the targets set for the given year. These targets must all fit with and contribute to the achievement of the Economic Development and Poverty Reduction Strategy (EDPRS) II (GoR, 2013) and Vision 2020 (GoR, 2000; GoR, 2012), and ultimately international goals under frameworks such as SDGs[20], which Rwanda also adheres to and has domesticated in the national development plans, including in the infrastructure sector (GoR, 2016d). Targets are measured against a number of economic, social and governance indicators- the performance indicators (Versailles, 2012). The same process is extended to all decentralised levels (districts, sectors, cells, villages (*umudugudu* in Kinyarwanda), and households), making the accountability both vertical and bottom-up (Graham et al., 2010). In order to successfully achieve any set national target, all levels must work towards it. Participation and contribution of citizens, as well as other stakeholders and partners working with various levels of the government, are crucial (Institute of Policy Analysis and Research ((IPAR-Rwanda), 2015) (see Figure 4.7). At the household level, families select a number of goals they want to achieve throughout the year (always starting in September). This can include installing a security light at the house, avoiding wasting family resources, or becoming a part of a cooperative. The number

[20] *Imihigo* and other planning strategies, including Vision2020 (GoR, 2000/2012), EDPRS II (GoR, 2013) and SE4All Agenda (SE4All, 2016) are set as either long-, medium- or short-term action plans. International frameworks would fall under long-term planning, but they are not part of *imihigo* per se.

and type of goals is determined by HH members according to their priorities, the availability of resources and the capacity to achieve these targets.

According to Klingebiel et al. (2016), there are three forms of community involvement which help achieve *imihigo* activities: central government's poverty reduction strategies including *Ubudehe* - a participatory problem solving mechanism encouraging community involvement in decision making and Vision 2020 *Umurenge* Programme (VUP), set up to speed up poverty eradication; *Umuganda* - community work that takes place on every last Saturday of the month with the aim to make progress towards a specific target and offers citizens a space for discussion of achievements, challenges and priority areas for their village; and financial and non-financial contributions from the citizens, including *agaciro*- a HGS aiming to enhance domestic savings mechanisms towards self-reliance and lesser dependence on donor support (Shyaka et al., 2016). This involvement is meant to enable the achievement of *imihigo* and strengthen the sense of ownership among all stakeholders. However, Hasselskog (2016) has argued that *imihigo* targets derive from the state and in the process of their formulation there is little participation and consultation which limits *imihigo*'s local relevance and the feeling of empowerment among citizens, making the performance contracts a governing tool in the hand of the state. Hasselskog & Schierenbeck (2015) have also criticised Rwanda's development programmes as being top-down rather than promoting local participation in the spirit of HGSs. Ansoms (2009) further argues that even though in principle making local governments responsible for the implementation of the *imihigo* should allow for easier translation into the local context and thus more adaptive towards community needs, the fact that at district, sector and cell levels the administrative power lies with a person appointed by the central government and not the community limits the extent to which it actually happens. Accountability also becomes problematic as the responsibility is to the central government rather than the people (ibid.). Despite existing criticisms, Scher[31] argues that the *imihigo* process has a role to play in delivering on the crucial development targets and McCord (2017) sees Rwanda's Vision 2020 programmes, including *imihigo,* as valuable programming options with more potential than other conventional Public Work Programmes (PWP) in the region.

The implementation of *imihigo* and the difficulties in monitoring and evaluation of targets as well as set targets being unrealistic, led the GoR to add the Results Based Performance Management (RBM) policy for Rwanda Public Service (GoR, 2015). This is intended to ensure timely implementation of national development objectives, as well as assist with national planning, monitoring and evaluation of targets, alignment of operations and evidence-based learning. Local participation and inclusiveness have been the guiding principles in the conception and implementation of the policy. The *imihigo* have continued to function and have been embedded in RBM policy as a tool to help with the planning, budgeting and policy review processes and various administrative levels (GoR, 2015). According to Kamuzinzi (2016), even though *imihigo* were initially conceived of as a HGS based on tradition, the combination of *imihigo* and RBM has turned into a hybrid management tool after the implementation of the RBM policy and now relies on the external control of performance which stems from the modern management philosophy.

Gaynor (2015) sees Rwanda's achievements in pushing its development agenda and introducing measures stemming from culture and tradition to improve effectiveness in execution as what some call the "new African developmental state". He puts under question the legitimacy of the fast-track reform and transformation process that has taken place in the country in the last decade and along with it the role of local communities. Despite the highly praised decentralisation and its participatory nature, there have been arguments showing that the tendencies in the implementation of development programmes and various policies tends to be very centralised (Newbury, 2011; Ansoms, 2009). Similarly, Mann & Berry (2015) offer a critique of the Rwandan developmental state claiming that Rwanda is using "the developmental infrastructure to deepen state power and extend political control" (p.1).

However, as argued by Leal & Azevedo (2016: 1), setting targets is "[…] crucial to the definition, effort and investment implied in any plan." They are useful and, indeed, imperative for the achievement of broader goals, such as energy access, and provide a sense of purpose and direction for any given sector, allowing for the setting of frameworks for action (IRENA, 2015). Central or bottom-up goals, and formalising of the social contract in the case of Rwanda, despite its centralisation, helps bring these targets to policy attention and management (e.g. Scher, 2010). A visualisation of the *imihigo* framework with the interactions within it is demonstrated in Figure 4.7 below.

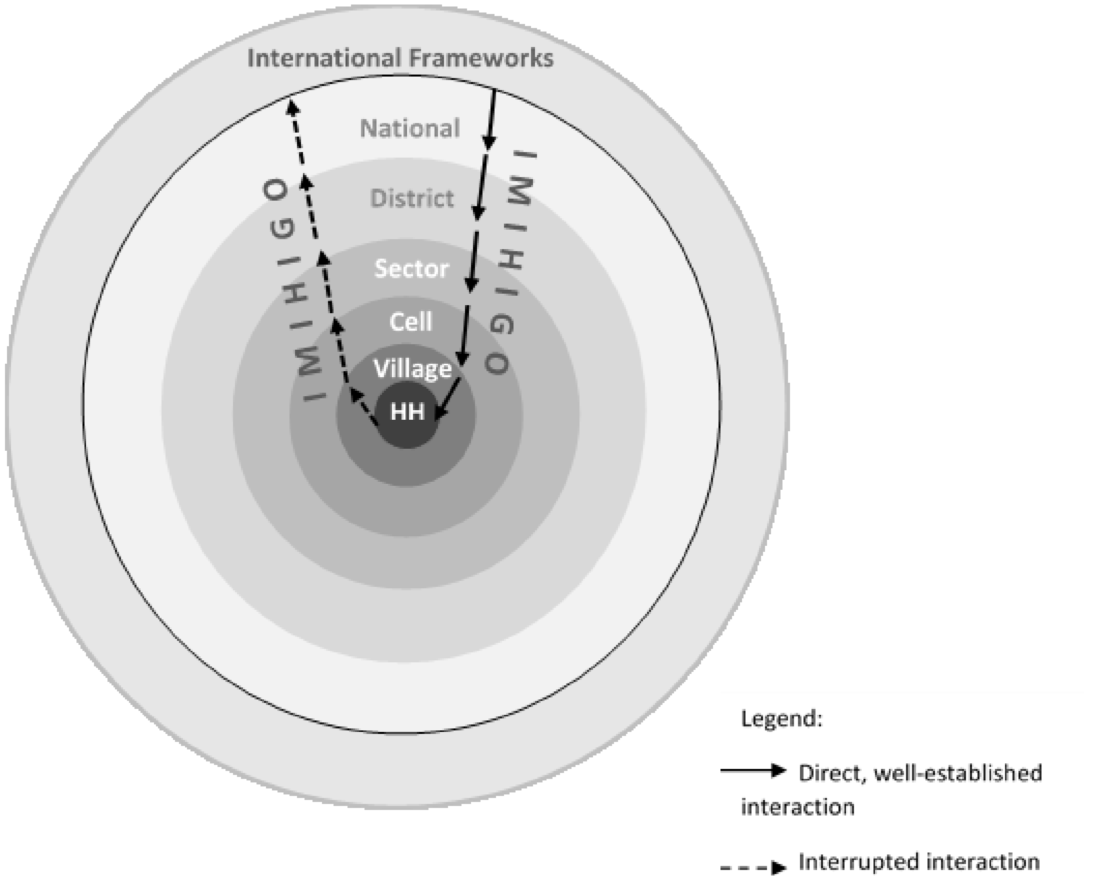


Figure 4.7. A simplified visualisation of Rwanda's multi-level imihigo framework. There should be a two-way interaction between the setting of imihigo at top and bottom level of the administrative ladder. However, as shown in section 3, there appears to be a breakdown in the bottom-up influence of HH priorities on higher level agendas, hence the dashed arrow lines.

4.1.2.3 Energy policy in Rwanda

Despite its turbulent past, Rwanda has experienced a considerable developmental progress in the last two decades (UNDP, 2010). The positive trends in its continued growth have been accredited to socio-economic transformations and a strong political leadership, along with well-defined targets and aspirations of becoming a middle-income country by 2020 (Baringanire et al., 2014; AfDB, 2012). In regard to energy access, Rwanda is currently leading the way to achieve the fastest rate of energy access growth, however, a large proportion of its rural population remains without access and clear disparities exist between rural and urban areas (SE4All, 2016). At 40.5% overall electrification rate in 2018, there is a lot of pressure to multiply both public and private sector efforts in order to achieve the planned 100% rate by 2024.

The energy access strategy was revised in late 2017 and the new targets were set. As of early 2018, electrification rate stands at 41% (29% on-grid and 11% off-grid), with the plans to achieve 100% electrification by 2024 (52% on-grid and 48% off-grid, including both SHSs and mini-grids). Milestones include connecting 100% of Kigali residents by 2019, 100% of productive users by 2022 and 100% of all users (including all households) by 2024. Access to electricity has been growing rapidly in the last 8 years, which is demonstrated in the graph below (Figure 4.8), and the Government of Rwanda has signed up to a number of strategic energy access initiatives in order to achieve the targets. A comprehensive overview of those initiatives is provided later in this section.

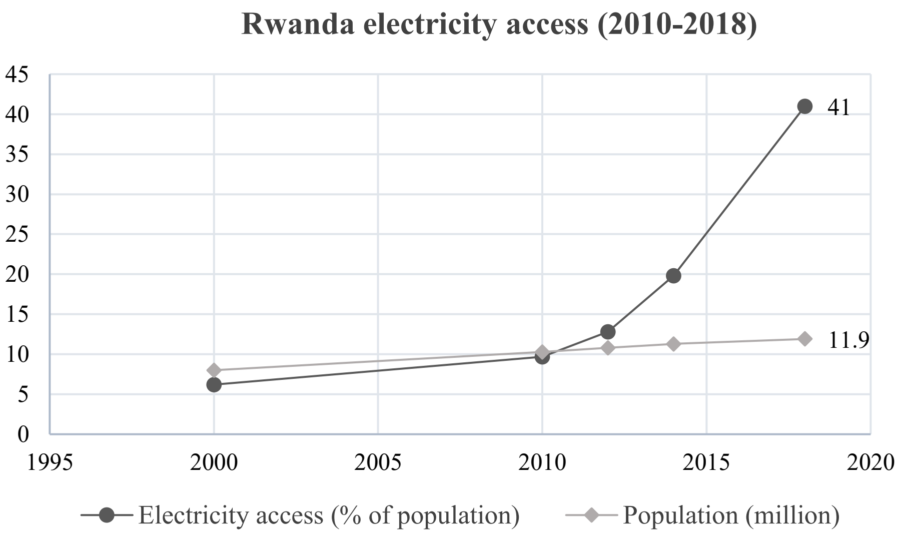


Figure 4.8. Access to electricity in Rwanda (2010-2018). The rapid growth in the last 8 years is clearly visible. Population has been growing slowly but steadily. Data source: SE4All (2018a) at < https://www.se4all-africa.org/se4all-in-africa/country-data/rwanda/>

As early as in 2000 when Rwanda's *Vision 2020* was put together, some of the key building pillars for the country's development were "[…] infrastructure, entailing improved transport links, energy and water supplies and ICT networks" and "[the development of] an efficient private sector spearheaded by competitiveness and entrepreneurship" (Newfarmer et al., 2013). Going against evidence from Mozambique and Tanzania by Ahlborg & Hammar (2014), who found that little interest of the private sector to invest in energy access and difficulties in planning were hindering progress, the case of Rwanda seems to point to the contrary. It has implemented short, medium and long-term planning strategies which include private sector's participation and aim to create a favourable business environment to attract investment, including in the energy sector. EDPRS (2008-2012) and EDPRS II (2013-2018) have both placed the role of infrastructure and energy access high on the priority agenda, with one of the four priority areas focusing on "Connect[ing] rural communities to economic opportunity through improved infrastructure" and acknowledging the need to meet the off-grid energy demand (GoR, 2013).

The Rural Electrification Strategy (RES) (GoR, 2016), which came into force in 2016, and the Sustainable Energy for All (SE4All) Action Agenda (SE4All, 2016) provide the framework for rural electrification through renewable energy. Rwanda's SE4All Action Agenda outlines 9 high-level energy targets, among them "[…] 100% electricity access by 2030 in both urban and rural areas through a mix of on-grid and off-grid solutions" (SE4All, 2016: i). This aligns with RES which specifically includes off-grid solar solutions (such as solar lanterns and SHSs) and private sector participation, not only through offering quality products but also by joining in the Rural Electrification Campaign launched by the Government of Rwanda as part of RES implementation. The campaign aims to raise awareness of most cost-effective energy access solutions among rural populations and promote off-grid systems for those unable to access the grid. Additionally, Rwanda has been selected as one of beneficiary countries for the Scaling up Renewable Energy Programme (SREP) in Low Income Countries (WB, 2015). The programme aims to show the socio-economic and environmental viability of renewable energy for energy access and the creation of new economic opportunities to drive country's development (ibid.).

4.1.2.4 Energy access imihigo

Energy access goals appear in all of Rwanda's key strategic plans, including *Vision2020* which in its updated version (GoR, 2012) also covers off-grid solutions, and in EDPRS II, both of which dictate the development of action plans at lower administrative levels, among them District Development Plans (DDPs) and Sector

Development Plans (SDPs). The annual action plans and *imihigo* are also set according to the national-level, long-term agenda[21].

At the highest level, energy access *imihigo* mostly fall under the responsibility of the Ministry of Infrastructure (MININFRA) and the Rwanda Energy Group (REG) with its subsidiaries: Energy Development Corporation Limited (EDCL) and Energy Utilities Corporation Limited (EUCL). Institutional *imihigo* are set individually by institutions while at the same time Joint Imihigo are set yearly as collaborative efforts among institutions to achieve certain targets. An example of REG *imihigo* 2016-2017 can be seen in Figure 4.9. There are separate targets for on-grid and off-grid electrification with specified numbers of connections (e.g. over 255,000 for the year 2016-2017), quarterly targets and clearly outlined indicators.

[21] Both Vision2020 and EDPRS II are here considered as long-term strategy plans.

REG IMIHIGO 2016/2017								
Output	**Indicator**	**Baseline**	**Targets/Milestones**				**Activities to deliver output**	**Budget/Rwf**
			Q1	**Q2**	**Q3**	**Q4**		
	Number of Households connected to the new grid electricity in east province	133,371 connections	2115 Connections	2115 Connections	2115 Connections	2116 Connections	1) Build small lines to connect located households MV line, Line TRANSFORMERS 2) Connecting located households	10600438702
Output 1.2 255,550 households connected with off-grid systems through partnerships with private companies	Number of Solar home systems installed in households	3,488 Mobisol Solar Energy Home Systems installed in households	Preparation and submission of the 3rd purchase order to Mobisol	1,400 Mobisol Solar Energy Kit Systems delivered	Preparation and submission of the 4th purchase order to Mobisol	1,963 Solar Energy Kit Systems delivered	Supervision of the Installed Mobisol Solar Systems Mapping of off-grid areas and share it with Mobisol for customer mobilization Coordination with the Governmant Local Authorities Supervision and reporting on the project progress status	1929988750
	Households with access to off grid solar PV systems	None	Determining the subsidy scheme to system beneficiaries	84,000 households connected to off-grid electricity	84,000 households connected to off-grid electricity	84,187 households connected to off-grid electricity	**EDCL** Mapping of off grid areas for project location Coordination with the Governmant Local Authorities Supervision and reporting on the project progress status Approving of subsidies for the system beneficiaries **IPPs**	Private

Figure 4.9. Rwanda Energy Group Imihigo 2016-2017. An example of institutional imihigo outlining electrification plans for 2016-2017 through both on-grid and off-grid connections with an explicit incorporation of partnerships with the private sector for off-grid energy provision. Source: adapted from GoR (2016a). RWF1000 = USD1.12 (Exchange rate from 16/07/2018).

DDPs and SDPs will further include energy targets broken down according to the region. Most importantly, however, households adopt energy targets which are included in their yearly performance contracts (*Ikayi Y'Imihigo Y'Umurango*). These contracts, in a form of a booklet containing a list of 61 optional targets under three pillars (Good Governance and Justice, Family Economy, and Good Conduct) from which families can choose as many or as few as they wish, and to which they can also add their own targets, get distributed to all households on a yearly basis (MINALOC interview, 2016). There are no *imihigo* set as getting energy access per se but rather there is a number of individual targets which require access to energy, such as "To own a radio, a phone and a TV, and to be able to get access to other available technology and new products" and "To own a security light at each house" (both under the Good Governance and Justice pillars) (GoR, 2016c). Another *umuhigo* which refers to energy is "To have biogas or other gas which can be found where you live" (under the Family Economy pillar) which refers to an energy source for cooking. While in this case a specific source is suggested (biogas or any other gas), in the case of the other two *imihigo* no energy access options are mentioned. The scope of the targets, however, seems to be compatible with what standard off-grid SHSs are capable of supporting: typically, phone charging, powering a radio and a TV (optional and at a higher cost), and providing light, including outdoor security light. Smaller capacity solar lanterns (pico-solar systems) can also support lighting and phone charging, and in some cases a small radio.

4.1.2.5 Elaboration on research methods

As discussed in section 3.1.3, 218 survey respondents were asked questions which included those specifically focusing on the *imihigo* as the researcher learnt about the village and household-level energy targets in stakeholder interviews, after the surveys had already commenced, and the *imihigo* questions were added a few weeks into data collection. Additionally, this part of the research was informed by the series of semi-structured interviews with some of the stakeholders involved in Rwanda's energy sector, including the Ministry of Infrastructure, EDCL-REG, FONERWA, GIZ and Energising Development, and representatives of local administration and *imihigo* experts from the Ministry of Local Government, as well as a representative of the Rwanda Governance Board. A review of relevant documents concerning Rwanda's energy policy and development planning was also carried out. Among them, Rwanda's Rural Electrification Strategy, Rwanda's Vision 2020, Ministry of Local Government, Ministry of Infrastructure and Rwanda Energy Group *imihigo* 2015-2016 and 2016-2017, and SREP Investment Plan for Rwanda. FG2(6-10) included questions on *imihigo* and findings from those focus groups were used along with the above-mentioned data sets.

4.1.2.6 Research results

4.1.2.6.1 Household and village level energy *imihigo*

218 users of SHSs (all of whom were BBOXX customers at the time of data collection) took part in the survey. Questions were asked about household-level as well as umudugudu-level energy *imihigo.* First, participants were asked about whether there were household-level *imihigo* which focused on getting access to energy at the time when they purchased their SHS. As demonstrated in Figure 4.10, 41% responded yes versus 55% who responded that there were no household-level energy *imihigo*. 4% said that at the time there were no household-level *imihigo.* At the household level, *imihigo* adoption begun later than the national *imihigo* which were introduced by the GoR in 2006. Respondents reported adopting household-level *imihigo* between early 2012 and late 2014, depending on the sector they live in.

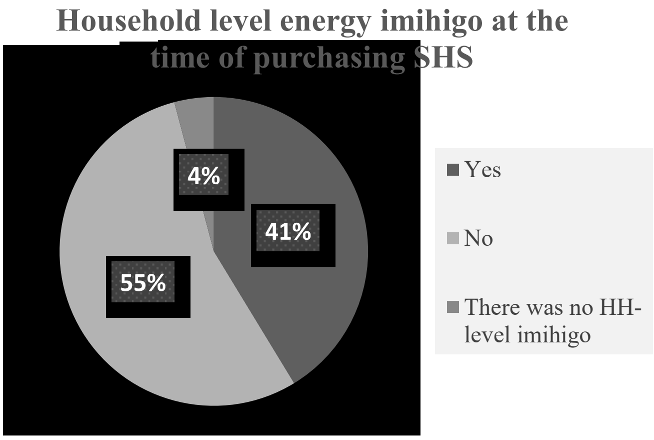
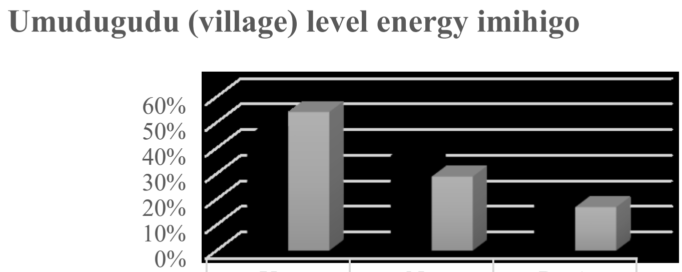


Figure 4.10. Percentage of interviewed BBOXX customers whose households had energy imihigo vs those who did not have them at the time of purchasing a SHS. 4% did not have household-level imihigo at all at the time (i.e. they were not using the imihigo framework at all in their households).

Another two questions asked about umudugudu-level energy *imihigo* at the time of purchasing a SHS and umudugudu-level *imihigo* now (i.e. at the time of participating in the survey). As shown in Figure 4.11, there has been an increase of approx. 10% in umudugudu-level energy *imihigo* in the period between when customers purchased their SHSs and when the survey took place. The proportion of respondents who were not aware of umudugudu-level energy *imihigo* dropped only marginally therefore with time there has been an increase in the number of imidugudu[22] adopting energy access targets.



	Yes	No	Don't know
■ At the time of purchasing SHS	44%	37%	18%
■ Now	54%	29%	17%

Figure 4.11. Umudugudu-level energy imihigo at the time customers purchased SHSs and now (July-Sept 2016).

Excluding those who reported not having household-level *imihigo* at the time of purchasing a SHS (a total of 9 respondents, making it a sample of n=209), households in villages where there were energy *imihigo* (and they were aware of them) were 56% more likely to have household-level energy *imihigo* than households in villages where there were no energy *imihigo.* They were also 27% more likely to have household-level energy *imihigo* than households unaware of whether or not there were village-level energy *imihigo* at the time they purchased a SHS.

[22] Plural of *umudugudu.*

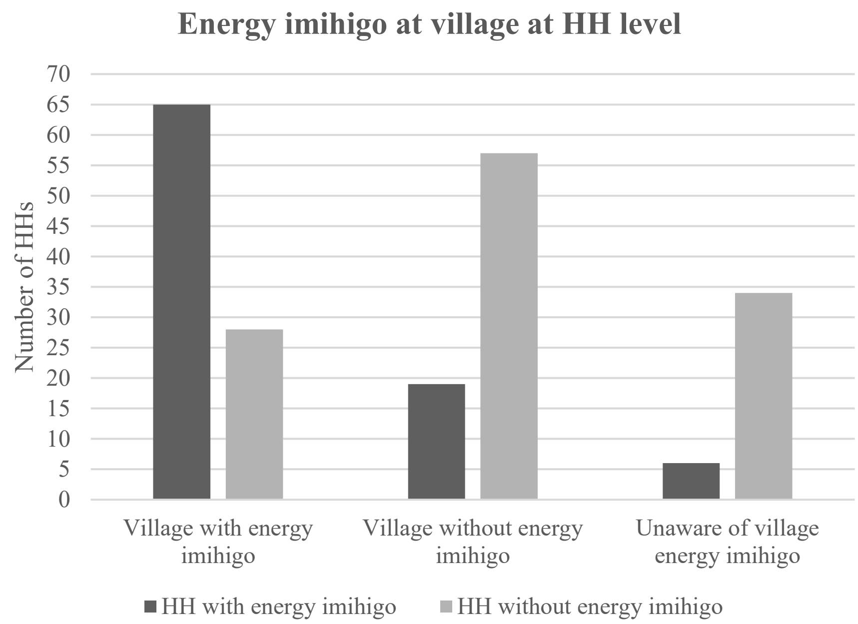


Figure 4.12. Energy imihigo at village and household level.

Awareness of village-level *imihigo* might be an important factor influencing people's decisions regarding their own *imihigo* choices. Ensuring energy access (incl. off-grid options) is among them might help increase uptake. Existing spaces, such as *umuganda* are well-fitted to be the ground for community discussions and awareness raising. However, when asked about where the motivations to purchase a SHS came from, for only 1% of respondents was it a cell meeting.

4.1.2.6.2 The imihigo process

Five focus groups with a total of 30 BBOXX customers (25 men and 5 women, aged between 19 and 82) from different imidugudu were conducted as a follow up to the survey in order to further explore questions of energy *imihigo* in the SHS users' households and villages. There were four main topics of discussion: 1) how households decide on what *imihigo* to choose, 2) whom the households are accountable to and how the *imihigo* process works, 3) how common energy *imihigo* are and how/why they get chosen, and 4) how households decide on what energy sources to choose, and whether those decisions are influenced by the umudugudu-level *imihigo*.

There were three key factors influencing households' decisions on the choice of: how much one earns (financial), which was usually mentioned first, followed by what it is that a family would like to have in their household or what they believe is important or necessary to have in the coming year (needs and aspirations), and finally what is achievable throughout the year of new *imihigo* (achievability). The process of choosing and signing the *imihigo* that have been selected by households for each year did not appear to vary much across villages. The flow chart below (Figure 4.13) demonstrates the steps as reported by focus groups participants:

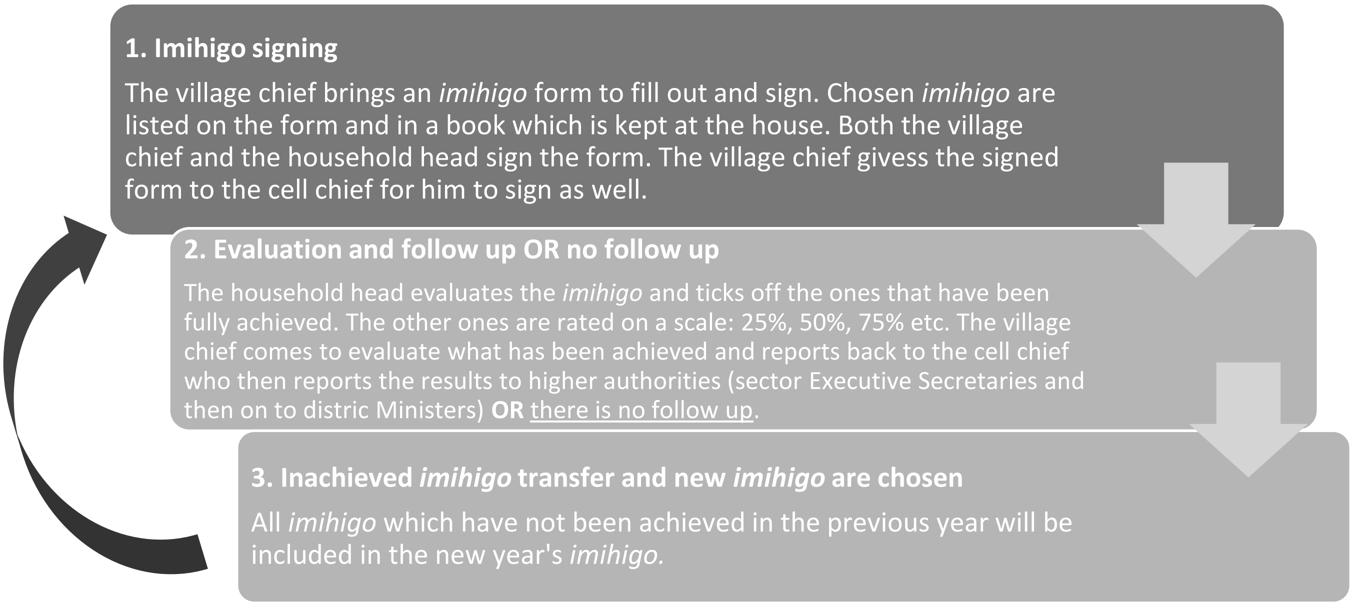


Figure 4.13. The imihigo yearly process as reported by the participants of focus groups.

The accountability appears to be vertical, as mentioned earlier (Graham et al., 2010), first to the village chief who evaluates the achievement of household *imihigo*, and then the cell chief to whom the village chief reports. The cell chief then takes the evaluation reports to higher authorities (i.e. the sector office). In one focus group, participants said there was no follow up at the end of the year so that the accountability falls solely on the family members, whether or not they have achieved the set targets.

When asked about how common energy *imihigo* are, 93% of participants responded saying that energy *imihigo* were common in their villages. They are decided at the district level which is where the categorisation of various *imihigo* that are to be achieved throughout the year takes place. Included in the district-level *imihigo* are energy targets which then trickle down to the cells and villages. The form that is brought to the household by the village chief contains different categories of *imihigo* and, among them, there are energy *imihigo* as well. Families then decide themselves whether or not to select the energy *imihigo* as one of their targets for the coming year, depending on the factors which have been mentioned above. If energy *imihigo* are adopted by the household, choosing the energy source is entirely up to the household members and it is never a decision influenced by the village-level decisions. Choosing what option of energy source to go for depends on a) what is available, b) whether it is a safe source, c) how much it costs and d) how much money is earned at the household.

What the participants kept stressing in the discussions was the flexibility of the *imihigo* and how the ones that have not been achieved in one year can then be transferred to the following year's *imihigo*. As much as the list of *imihigo* (both on the form brought by the village chief to sign and in the *imihigo* booklet which is kept at the house) is pre-determined, households are free to choose from various categories of targets and make those decisions themselves, with the option of making up and choosing their own *imihigo* which they can add on to the existing list. That flexibility aspect of the *imihigo* was what participants seemed to enjoy most and reported to be convenient for their households.

Focus groups discussions also confirmed the different times at which households started adopting household-level *imihigo*. Among those participating, they varied between early 2012 to late 2014.

4.1.2.6.3 End-user consultations

A series of short semi-structured interviews with seven of the key stakeholders in Rwanda's energy sector took place between June and November 2016. The interviews focused mostly on the level of understanding of, and consultation with, the end-users in the energy planning and provision, and on the role of *imihigo* for energy planning at various administrative levels.

On the one hand, a good overall understanding of what the end-users want and need was reported, particularly among the stakeholders working on the rural electrification strategy implementation and focusing on those still unelectrified. However, the consultations with end-users appeared to be limited and would often be as short as a couple or a few days. In spite of what seemed like a relatively short time spent on gathering end-users' feedback, "we know what people want" was a common response to the questions on how important understanding end-users' needs and aspirations is in the process of electrification planning. On the other hand, there was a sense of needing more understanding of the users of off-grid solutions as well as grid-connected rural households. Knowledge about whether or not their needs are satisfied and how energy is used in the households was limited as a result of little to no follow up on those who have been provided with connections, whether on or off the grid. Efforts to collect customer feedback from private providers, who have access to users of off-grid solutions have been stressed by stakeholders whose work in particular involves collaboration with the private sector. Gathering all that information in a systematic way and one which would allow to make it possible to include it into the planning and implementation strategies was reported to be challenging as private providers have distinct ways of collecting customer feedback and, most importantly, of sharing it.

4.1.2.7 Challenges and opportunities

The performance targets framework was also discussed with representatives of the Ministry of Local Government (MINALOC) (SI8 & SI9), in charge of it at lower administrative levels, including with experts focusing exclusively on *imihigo*, and with a representative of the Rwanda Governance Board, whose work spans Home Grown Solutions, research, political organisations and NGOs, as well as service delivery, policy advocacy and strategic engagement, including activities related to *imihigo*.

It was confirmed by MINALOC that not all households implemented *imihigo* at the same time and the speed of implementation varied across districts. One of the challenges brought up by MINALOC representatives was the difficulty with dissemination of *imihigo* booklets which do not reach all households either as a result of sector offices not being ready and operational at this point, and thus not having the capacity to deliver the booklets, or due to insufficient number of booklet copies being printed every year. There have been efforts to address this problem by providing sector offices with printers and paper to print out the booklets themselves and distribute in the areas they are responsible for. Regarding participation, according to MINALOC, villages and cells participate in the *imihigo* design process through planning and budgeting sessions, and their feedback is taken into consideration when deciding district-level *imihigo* for each year.

As previously mentioned, there are three pillars of *imihigo*: economy, social protection and governance, as well as three main types of *imihigo*: institutional, joint (which are collaborative and involve more than one institution), and district *imihigo*. In addition, since early 2010s, households have household-level *imihigo*. Access to energy (off-grid and on-grid) and the wider energy sector fall under the economy pillar within all types of *imihigo*. As was reported by MINALOC (SI8), the 2016/2017 target for off-grid electrification was to connect 40000-60000 households by 2018. For people without access to electricity who belong to Ubudehe 1 (programme) the government are supposed to provide access to off-grid solutions with a use of subsidies. However, not everyone is aware of which category of Ubudehe they belong to and, additionally, there have been attempts by those in higher Ubudehe to downgrade to Ubudehe 1 for the purposes of receiving free access through the subsidy scheme. This poses a number of challenges for the authorities to manage the process and ensure access is given to those who most need it and are unable to afford it. According to the Rwanda Governance Board, the Ubudehe 1 subsidy scheme is seeking to get contributions from international stakeholders in order to be able to provide off-grid electrification to the poorest as government resources are limited. The government, however, are doing more towards promoting off-grid electrification and helping reach the energy access targets. As part of biannual Governance Month, which each time has a different focus related to Rwanda's development, in September and October 2016 the Ministry of Infrastructure (MININFRA) and the Rwanda Governance Board (RGB) led a series of awareness-raising events held in the Western Province, in remote rural locations and the timing coincided with that of the launch of the Rural Electrification Campaign. It was stressed by the RGB that strong partnerships with private companies and collaborative and committed local authorities will be key to achieving the off-grid electrification targets (SI11). This opportunity has now been fully embraced in the scaling up of energy access efforts.

4.1.2.8 Discussion and policy recommendations

DRE options, and among them SHSs and smaller scale distributed solar systems, already play an important role in Rwanda's electrification efforts and will continue to do so given the off-grid electrification targets. Research has shown that off-grid solar is increasingly showing a better cost-benefit performance than grid-based electrification in rural locations, therefore justifying its viability as a reasonable option to pursue (Grimm et al., 2016). Additionally, large-scale grid extension programme in Rwanda has seen an increase in the number of connections but the appliance uptake and energy consumption have remained low (Lenz et al., 2017) which provides another proof for the viability of utilising solutions such as SHSs. In order to achieve the 100% off-grid electrification rate by 2024, Rwanda will need to intensify its engagement with the private sector and international stakeholders. Moreover, it will also have to address a number of challenges to rapidly boost SHS uptake, including raising awareness and activating demand, nurture a participatory environment so that broader needs are represented, and trust in grid alternatives is fostered. According to Common Market for Eastern and Southern Africa (COMESA) (2016: 5), "[r]ural electrification must be public led, with adequate incentives for private sector and cooperatives participation."

Through government-led energy planning and implementation strategies and appropriate framework design assisted by international stakeholders, Rwanda has made a lot of progress conducive to energy poverty alleviation. The existing framework of *imihigo* -- now well-embedded in the strategic planning process -- could be additionally used to enhance the GoR's and the private sector's energy access efforts, offering better targeted off-grid electrification planning and provision.

Results of this research show that users of SHSs in villages which had energy targets set at the time they purchased their systems were more likely to have household-level energy *imihigo* than those users in villages which did not have such *imihigo* or where there was no awareness of them. Clearly set village-level *imihigo* therefore have the potential to impact on the prioritisation of gaining energy access among households. Knowing where there is a high prevalence of household-level energy *imihigo* could assist private sector providers of DRE to plan their market strategies in a more targeted manner and piggyback on the already existing demand for energy access instead of having to build it from scratch. Given that the *imihigo* booklets get distributed to all households and that options such as biogas are explicitly mentioned, adding off-grid solar solutions to the existing list of energy-related targets could further boost awareness and potentially grow demand. Additionally, as these contracts are official documents administered by the Government, the inclusion of off-grid solar solutions could also build trust and increase acceptance as they are a demonstration of the Government's support of these options (similarly to the case of biogas), as is the REC which actively promotes off-grid solutions among rural communities.

Moreover, *imihigo*'s consultative nature and their evaluation both at the village and household level provide an opportunity to gather feedback and learn more about people's energy needs and any access barriers they might encounter (e.g. financial) in case their energy targets are not met. Participation and bottom-up planning being challenging to design, the *imihigo* (along with *umuganda*) could also be used as a tool to drive the desired end-user consultation processes and feed into the planning at higher administrative levels, which is currently done to a limited extent. This would allow for an improved interaction between the households and villages, and sector and district energy planning, making it a two-way dialogue rather than a top-down one. This could in turn boost the sense of empowerment, ownership and create a more inclusive policy environment. As revealed by stakeholder interviews, the need to improve end-user consultation and understanding is still there.

In itself, the approach to designing the energy delivery model can determine attitudes of end-users and help address at least some of the key identified barriers to adoption, namely affordability, accessibility, availability, approval (or acceptance) and awareness (RDB, 2017; Shell Foundation, 2014; Ballanca & Garside, 2013). Openly sharing feedback, from both off-grid connected users as well as those still unelectrified, with the private sector could enable better business model design driven by the different needs, aspirations and realities, and provide guidance for the public sector as well.

However, in order to fully realise the benefits that could be drawn from the *imihigo* and the tools that they offer, it is important to address the distribution challenge head on which was mentioned by MINALOC for more effective dissemination. The issues of end of the year evaluation follow up by the village chief, which was reported absent in some villages, could also hinder progress as it implies a missed opportunity to understand what enables or prevents households from reaching their targets. Similarly, the village-level consultation processes feeding into the design of SDPs and DDPs appear in need of attention as research participants' understanding is that *imihigo* are decided by district offices and the sense of ownership does not trickle down. The strong dependence of the working of *imihigo* on the village chief points to the importance of his or her performance for the overall success of driving and monitoring electrification progress, and further to the need for adequate capacity building of strong local authorities and leadership (GoR, 2015). Including energy access discussions and targets into agendas for community meetings (at the village and cell level, including during *umuganda*) could contribute to further dissemination of information and, in turn, encourage consideration of off-grid electrification among greater number of those with no grid connection. Ensuring the voices of HHs and communities are taken up to higher administrative levels could help avoid the breakdown of bottom up participation (mentioned in section 4.1.2.2 and Figure 4.7) and therefore the risk of HHs' needs, priorities and challenges not being taken into consideration when deciding on the yearly development agendas.

Learnings from Rwanda's approach and established mechanisms that carry the potential to speed up its rural electrification, as well as from similar approaches which have proven successful in assisting off-grid electrification, such as China's Results-Based Strategic planning and participatory governance practice (Chen, 2016; Wang & Lin, 2014; Xianli et al., 2014), could be applied to other countries, both regionally and globally. Maximising their strengths and addressing the challenges could enhance the already favourable environment in which off-grid solutions are playing a role in last mile electrification.

Other examples of frameworks based on historically and culturally embedded philosophies (although not specifically comparable to *imihigo*) include the Sufficiency Economy in Thailand and the Gross National Happiness (GNH) development framework in Bhutan. The former is based on the Bhuddist tradition and promotes moderation, reasonableness and prudence in socio-economic and human development, encouraging everyone (individuals, groups, communities, businesses etc.) to follow the three domains through the principles of knowledge and virtue (Ministry of the Foreign Affairs of the Kingdom of Thailand, 2016). Bhutan's GNH, on the other hand, consists of 9 domains and 33 sub-domains related to e.g. psychological well-being, time, education, health, as well as living standards within which included is access to electricity (Ura, 2015). Both have been supportive of bottom-up and resilient development, including energy access in Bhutan.

When designing similar frameworks, based on the learnings from Rwanda's *imihigo* approach, particular attention should be paid to the socio-cultural context and sensitivity which aids achieve high levels of acceptance. Transferability of this kind of framework can be either eased or challenged depending on whether or not there exists a culture of target setting in any given context. At the same time, other tools stemming from history or culture might be useful in driving the design of similar approaches and should be leveraged for the achievement of culturally appropriate solutions. Transparency in establishing accountability and commitment in managing the execution of processes, with a clearly defined participation and contribution of individuals (and/or groups of individuals) throughout the administrative ladder are also crucial for ensuring that *imihigo* at lower administrative levels are fully incorporated into the multi-scalar planning framework. When focusing specifically on energy access policies, raising awareness of and providing education on available solutions, such as off-grid systems (whether solar-powered or otherwise), will enable faster and higher uptake among unelectrified households, thus speeding up electrification efforts. As advocated in this paper, approaches such as *imihigo* or similar (e.g. Thailand's Sufficiency Economy or Bhutan's Happiness Index) can also be used to that end.

4.1.3 Market actors and other decentralised energy technologies

The Government of Rwanda have partnered with 24 off-grid companies to provide off-grid energy access through SHSs to households across the country, prioritising areas where grid extensions are currently not planned. The pre-requisite to become a partner company was to gain the Lighting Global certification for all their products (Kesrelioglu, 2018), to ensure quality and reliability, as well as longevity of the systems. There are currently four key players in the SHSs space in Rwanda who have achieved some level of scale (systems sold in thousands rather than hundreds), namely: Mobisol, BBOXX, Ignite Power, and Zola Electric (previously Off Grid Electric). Several companies have entered the market in the last couple of years and are slowly growing their presence. One of them, for example, is Greenlight Planet who have partnered with One Acre Fund- an agricultural organisation working with farmers across the East African region (and beyond). Providers of smaller off-grid solar solutions, such as solar lanterns (or lamps), are also present in Rwanda and include Waka Waka, d.light, Greenlight Planet Sun King Pico Plus or Pro, and others. Examples of other SHSs available in Rwanda and solar lanterns can be seen below (Figure 4.14 and Figure 4.15).

Figure 4.14. An example of solar lanterns. Here, Sun King lamps as offered by Greenlight Planet. Source: Great Lakes Energy (GLE) (2018) at http://gle.solar/

Figure 4.15. A Mobisol SHS and accompanying appliances. Mobisol SHSs come with a bigger capacity panel (80W or 200W) than a BBOXX SHS which enables them to power off more appliances, including more energy-demanding ones. Source: Mobisol (2018) at http://plugintheworld.com/solutions/

The capacity of SHSs varies, however, the range of the most standard ones supporting basic appliances such as lights, torches, radios, phone chargers, TVs, shavers and the like, usually come with panels between 10W to 200W, where the latter is capable of supporting higher energy-demand appliances (such as is the case with the bigger Mobisol SHSs). They do, however, come at a considerably higher cost at typically $15 and more per month, as opposed to the most average ones (20W-50W) which are in the range of $5-$10 per month (if sold on a PAYG basis). A comprehensive list of all Lighting Global certified products, some of which are available to customers in Rwanda, can be found on the Lighting Global website which also includes individual specifications of all the systems and lanterns (Lighting Global, 2018). A categorisation of off-grid solar products, including their capacities and sales volumes between 2015 and 2016, for reference, can be found in Appendix 3.

In addition to the Lighting Global certified off-grid solar products, non-branded generic SHSs and solar lanterns are available for purchase off the shelf. Those products are sold on a cash basis (no PAYG) and typically cost between $30-$150, depending on the capacity and the appliances they contain, as well as the part of the country. Our findings show that generic SHSs from Uganda, which come at a cheaper rate than on average, are very common in the North of Rwanda, in areas close to the Ugandan border (those findings are discussed in section 5.2.7). Those products pose a lot of competition to the market of certified SHSs, however, recently companies have reported increasing brand awareness among customers (GOGLA, 2017). Awareness of off-grid solar solution providers among study participants is presented in section 5.2.1.

Other off-grid solutions for energy access present in Rwanda include solar and hydro mini-grids (e.g. MeshPower, solar mini-grids) and solar kiosks (e.g. NURU Energy), which serve as charging stations for either lights or take-home batteries which can power lights and phone chargers. Currently the saturation of the Rwandan market is not high enough to have all the above-mentioned providers of different off-grid technologies competing in one area. However, it is not uncommon to encounter at least 2 or 3 different ones in one village (e.g. a mini-grid and a SHS provider, with generic SHSs and solar lanterns available for purchase at the local market). Additionally, the Rwandan Government is in the process of designing a strategy which will see a clearer division of off-grid areas between various providers in order to achieve 100% coverage by 2024[23].

4.1.4 Energy carriers and devices

All HHs who have participated in this study were, at the time of data collection (split between 2016 and 2017), users[24] of BBOXX SSHSs. Despite differences in appliances

[23] At the time of writing, that strategy was not publicly available and therefore cannot be cited.
[24] Over time, a proportion of customers default and get their systems repossessed. Therefore, at the time of writing (early 2018), not all customers are still users of BBOXX SSHSs.

used by the pool of customers who took part in various data collection activities, all of them used SMART Solar Home Systems as provided by BBOXX, which all consisted of a 50W solar panel, 12V 17Ah battery contained within a Control Unit (CU) with an embedded remote monitoring technology. For a detailed description of the technology used in BBOXX's SSHSs and its advantages, as well as challenges, please see Bisaga et al. (2017) (Appendix 14). As per the World Bank's Multi-Tier Framework (Appendix 2) BBOXX's SSHSs fall under Tier 2 level of access although with only lights and phone charging, it could also be categorised as Tier 1, despite its capacity which far exceeds the minimum Tier 1 system requirements.

At the very minimum, customers would own two lights and a mobile phone charger (single). Additional appliances (more lights, portable light, mobile phone charger with multiple ports, TV, radio, shaver) were present among study participants in various combinations. For a detailed breakdown of system types owned by participants of S2 and S3, please see section 5.1.3. For system types owned by participants of PPWs, see Table 3.7 in section 3.1.4. System types and appliances used by participants of FGs (both round 1 and 2) have not been collected as the questions and the discussions were more general and did not focus specifically on what sets of appliances pertaining to the range of BBOXX SSHSs customers had access to.

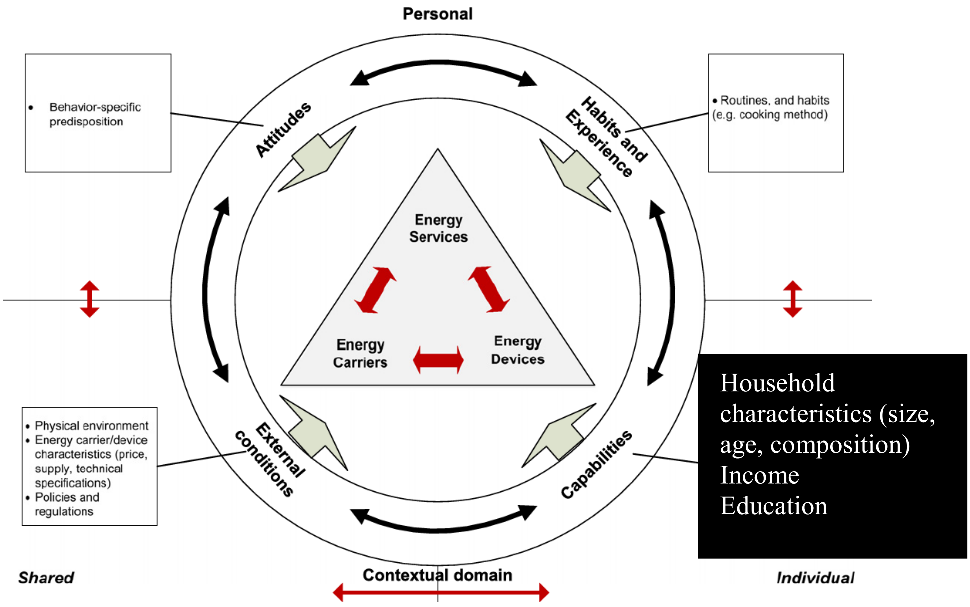
Examples of a standard BBOXX SSHS can be seen below (Figure 4.16).

Figure 4.16. An example of BBOXX SSHSs with various appliances. On the left: a battery box (i.e. the CU), a radio, phone charging USB cables (a selection of different ones for different phones), a torch light (portable light), a 9" TV, a shaded light. On the right: a set of light switches, two shaded lights, a TV, two non-shaded lights, a CU and phone charging USB cables.

All SSHSs rely fully on the solar energy received through the 50W panel and among participating customers none were grid-connected (although the battery can be charged through the grid if it is available). BBOXX utilises DC (direct current) solar technology with all its appliances running on DC power. Hence, a range of DC appliances is available to the customers and it is recommended that customers only use those provided by BBOXX for the sake of compatibility and to avoid draining the battery, as all appliances are super energy-efficient (all ranging between 1.2W-9W) compared to standard electrical appliances used with grid electricity, which are typically in the range of 5W-2000W (and more, depending on the appliance and its energy efficiency) and run on AC (alternate current) power).

All SSHSs are standalone and in the sample of all participating customers (and their HHs), there have been no cases of electricity sharing (e.g. extending electricity from one SSHS to a neighbouring house) or swarm electrification (combining two or more SSHSs together).

4.2 Capabilities



The quantitative analysis in this study relies primarily on the S2 and S3 which, as mentioned before, were designed with the same set of questions but were conducted in two ways: S2 was conducted among 97 users of SSHSs in their households whereas S3 was conducted with 168 users over the phone. The below results are drawn from those two surveys (collectively referred to as 'the survey'). Qualitative data from the 20 PPWs as well as from the FGs (although to a more limited extent given that FGs were always conducted outside of the HH and there were no opportunities to learn about or observe HH characteristics in the same way as during in-HH PPWs) follows the quantitative results.

4.2.1 Age distribution

The age distribution among S2 and S3 participants (n=265) is demonstrated below (Figure 4.18 and Figure 4.17).

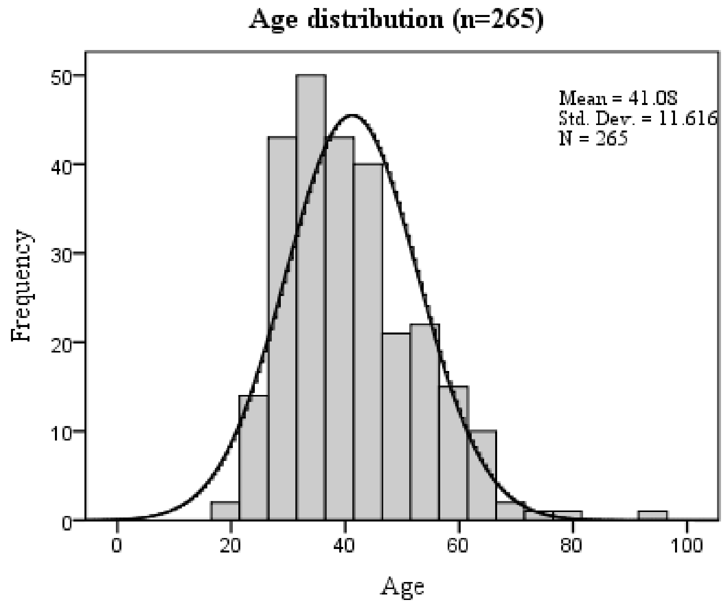


Figure 4.18. Age distribution among survey participants (n=265).

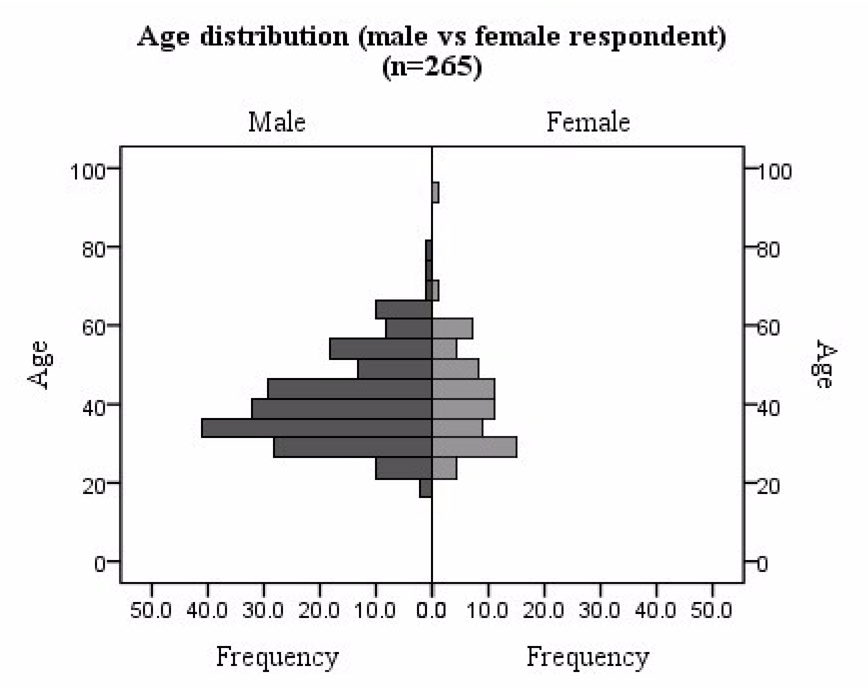


Figure 4.17. Age distribution of female (n=71) and male (n=194) survey respondents.

Mean recorded age was 41.08 years old (s= 11.616, median 39) and a range of 75 (min. 19yrs, max. 94yrs). Women were on average slightly older than men at 41.54yrs (SD=12.418) vs men at 40.91yrs (SD=11.338).

4.2.2 Gender composition

The total number of S2 and S3 participants was n=265, among which 194 were male and 71 female. Gender composition among respondents varied considerably between S2 and S3, which corresponds to the in-HH and telephone method of conducting the survey. Not all respondents were the owners[25] of SSHSs which is also reflected in the data below (Figure 4.19 and Figure 4.20). Those participants, however, were still considered to be users of SSHSs as they were adult members of the HHs where SSHSs have been adopted and represented the experience of their HH (albeit from personal point of view).

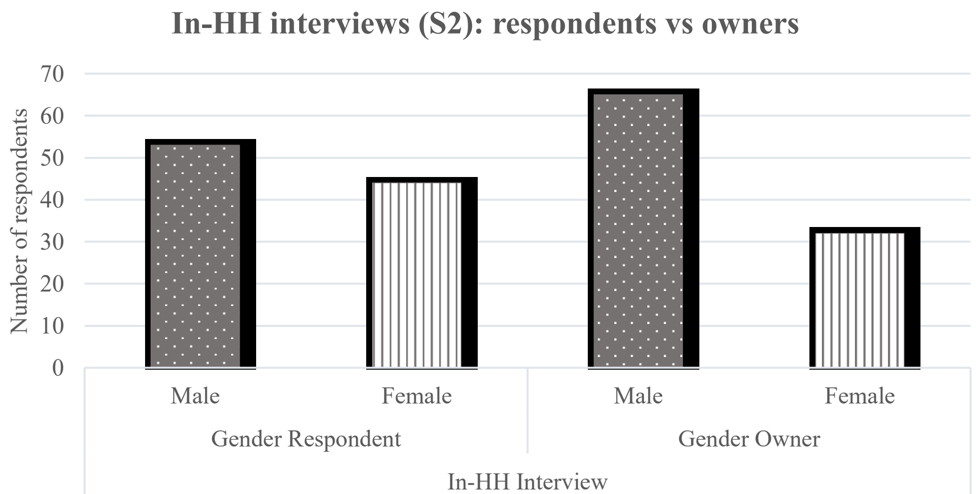


Figure 4.19. Gender composition of participants of S2 (in-HH) showing the split between survey respondents and system owners (n=97).

[25] A person in the HH who is registered with BBOXX as the owner of the system, i.e. their name appears on BBOXX's record of clients.

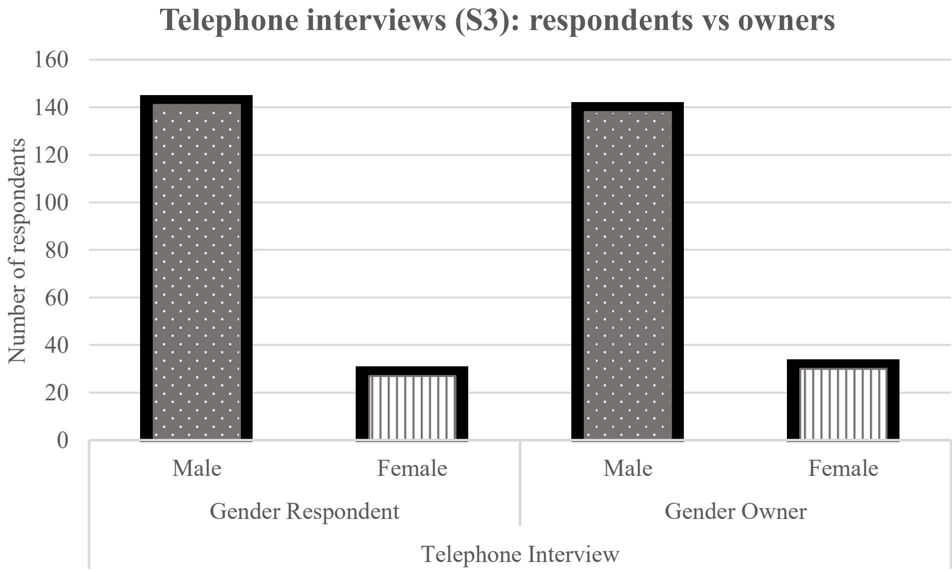


Figure 4.20. Gender composition of participants of S3 (telephone) showing the split between survey respondents and system owners (n=168).

The two figures above show a much lower presence of female participants in S3 as compared to S2 (27 vs 44) and the overall lower number of female participants in the entire sample (73.2% men and 26.8% women). Female respondents were much more likely to participate in in-HH interviews than over the phone, which is the result of considerably higher male ownership of SSHSs. The split between male and female system ownership is also visible in the above figures, particularly in the comparison of respondents and owners in the case of S2 where from among 44 participating women 32 were owners, whereas the number of male respondents was lower than that of owners in the n=97 (53 respondents vs 65 owners). The opposite was the case in S3 (telephone), but only by a very small margin: fewer women were respondents than owners and fewer men were owners than respondents but only by 3.

This split is consistent with the overall system ownership rates across all customers (as of April 2016, the time of sampling, shown in Figure 4.21), with a significantly higher proportion of male than female customers.

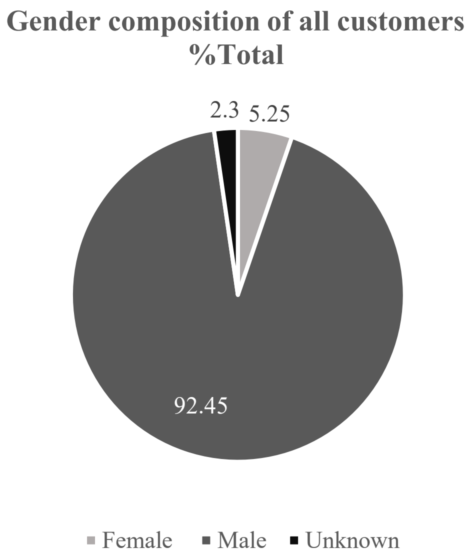


Figure 4.21. Gender composition of all BBOXX customers (recorded system owners, n=8681) on April 20th, 2016.

The relatively high presence of women in S2 (45.4% vs 54.6% men) was the result of two main factors: purposive sampling and the gendered division of roles in rural HHs in Rwanda, where women are the more likely ones to stay at home and take care of the house and the family. Given that all interviews were conducted in the hours of daylight, usually between 8am and 6pm, women were more likely to be found at home than men in S2 whereas for S3 that division was of less significance as participants were called on the phone. Phone numbers used were those of the registered owners, therefore in S3 we found it more likely to speak to men as they make up the majority of systems owners across the entire customer database. Purposive sampling to include women was also applied which resulted in the overall reach of 17.9% women and 82.1% men, which still represents a considerably higher proportion of women than in the total number of customers (Figure 4.21 above). In the case of FGs and PPWs, their participation was arranged through the RA in advance and over the phone, with the male owners usually reached. However, in PPW both men and women were encouraged to participate, and participation in FGs by men was replaced by women in the HH in instances where the men were unavailable, or where the woman was the owner/HH head. This gender split has been important for understanding differences in the experience of using SSHSs between male and female users and is discussed in the following sections and chapters.

The ownership of different SSHS packages according to gender is demonstrated below (Figure 4.22). More male than female owners have adopted a BB Lights package, while the ownership of BB Super Lights and BB TV packages is almost evenly spread between the two groups. More female than male owners have chosen both Ikaze and Aguka packages, which also coincides with a higher proportion of female owners in Group 3 (<6 months) which was the time of switch from BB packages to Ikaze and Aguka.

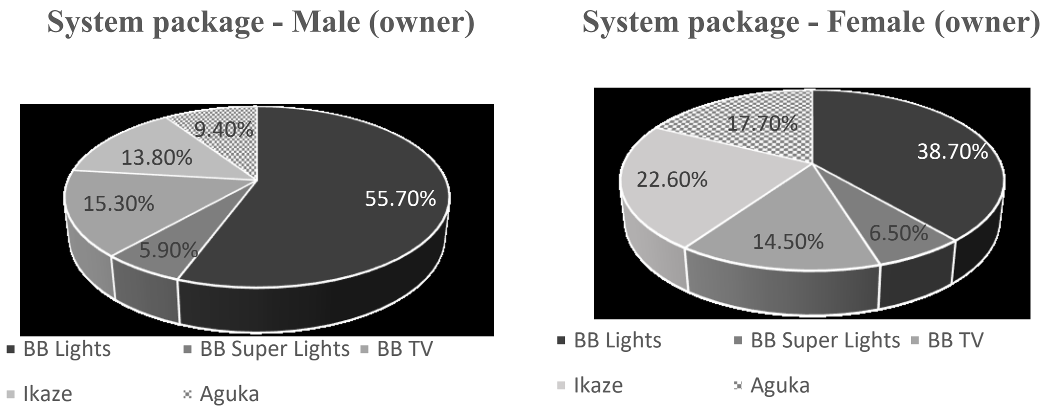


Figure 4.22. System package ownership by gender: male (n=203) and female (n=62).

Majority of further results presented in this study will focus on the 'respondents' rather than 'owners' (unless otherwise specified) as they are the ones who answered the survey questions. Whether owners or not, they are collectively called users/adopters/customers, interchangeably.

4.2.3 Poverty likelihood

The Poverty Probability Index (PPI) (previously called Progress out of Poverty Index) has been used to measure poverty levels among S2 and S3 participants. PPI is a statistically-sound poverty measurement tool which relies on a standardised set of 10 questions designed for each country individually, taking into consideration the most relevant poverty indicators pertinent to the local context (such as type of roofing, number of beds, number of adults working for profit etc.) (PPI, 2018). It was originally created by the Grameen Foundation with the support of the Consultative Group to Assist the Poor (CGAP) and Ford Foundation and is currently managed by Innovation for Poverty Action (IPA)[26]. This methodology was selected as a more reliable one than measuring poverty based on self-reported income levels which tend to be misrepresented and skewed when working with groups whose incomes can be highly seasonal and variable, and therefore obtaining a reliable set of data on incomes has been proven very challenging.

The assumed poverty level was under $2.50/day (2005 PPP[27]) which corresponds to the standard poverty lines used by various international organisations. The higher on the scale from 0-100 the HH scored, the more it was to fall under the $2.50/day poverty line (i.e. the more likely it was to be poor). The results were split into three groups according to the poverty likelihood (based on the score): a) low likelihood (of living below $2.50/day) (low likelihood of poverty or LLP) with score <30, b) intermediate likelihood (ILP) with score 30-60, and c) high likelihood (HLP) with score >60. The split between the three groups is demonstrated in Figure 4.23 below. The x-axis indicates the score obtained by the HH (according to the participating respondents' answers) in the standardised 10-question survey added to each interview.

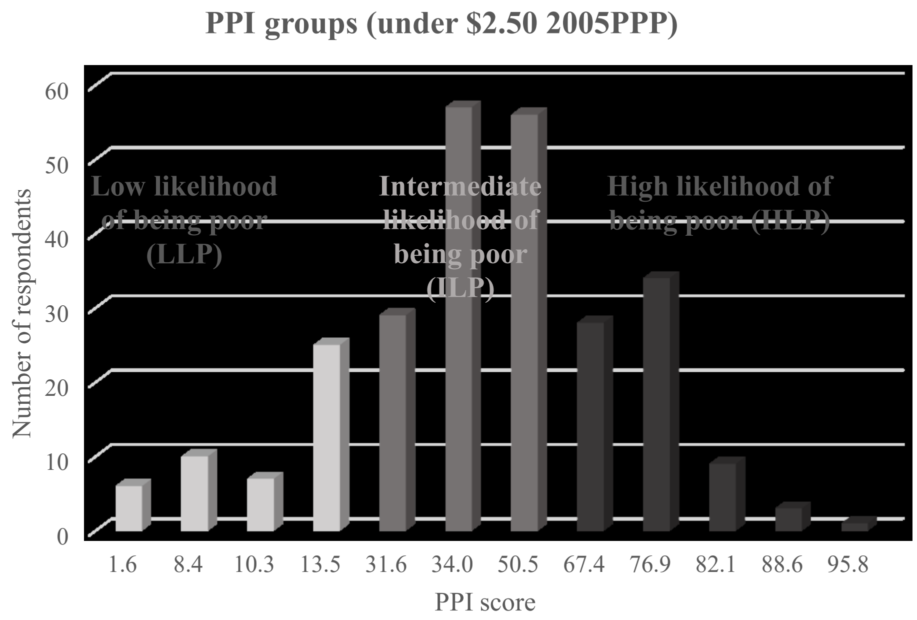


Figure 4.23. Split of under $2.50/day poverty probability in n=265. Graph shows the three groups: low likelihood of poverty (LLP, left-side range), intermediate likelihood of poverty (ILP, middle range) and high likelihood of poverty (HLP, right-side range).

[26] Further details on the methodology can be found on the PPI website at https://www.povertyindex.org/about-ppi and the methodology guide with questions and scorecards for Rwanda has been attached in Appendix 10.
[27] Purchasing power parity.

The highest proportion of the survey participants fell under the ILP group (42.6%), with a lower but very close percentage of participants falling under LLP group (29.1%) and HLP group (28.3%), as demonstrated in Table 4.1.

Poverty Group (under $2.50) (2005PPP)				
		Frequency	**Percent**	**Cumulative Percent**
Valid	Least likely to be poor (**LLP**)	77	29.1	29.1
	Intermediate likelihood of being poor (**ILP**)	113	42.6	71.7
	Most likely to be poor (**HLP**)	75	28.3	100.0
	Total	265	100.0	100.0

Table 4.1. Division of survey participants (n=265) into three poverty groups according to PPI.

Poverty likelihood between male and female owners is shown in Figure 4.24 below. The split across the three groups (LLP, ILP and HLP) differs only minimally, making the difference insignificant.

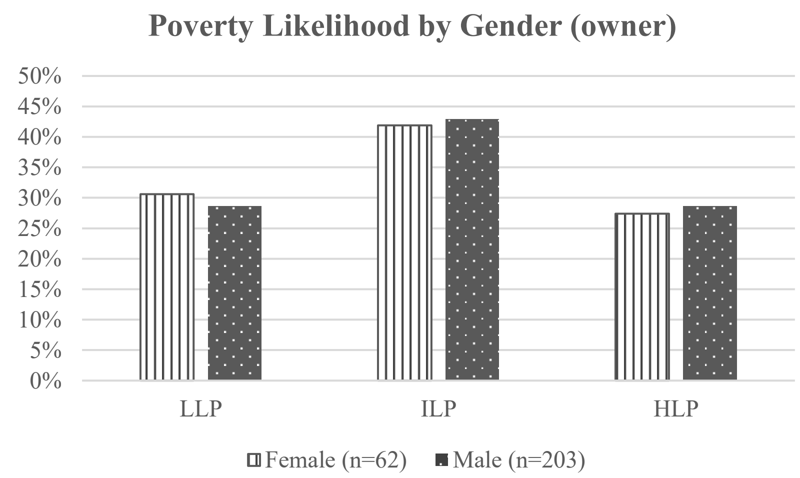


Figure 4.24. Poverty likelihood by gender of system owner.

4.2.4 Household size

Participating HHs had on average 5.64 (SD=2.05, median 6) members, ranging between min. 2 and max. 14 members, as shown in Figure 4.25. This is higher than the average HH size in the entire population, which at the time of sampling was 4 (as previously discussed in section 3.1.4).

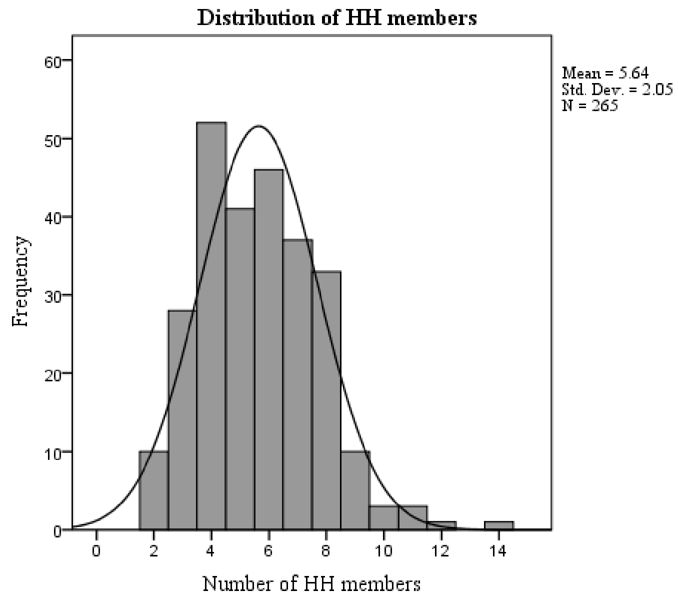


Figure 4.25. Histogram demonstrating the HH members distribution in the survey sample (n=265).

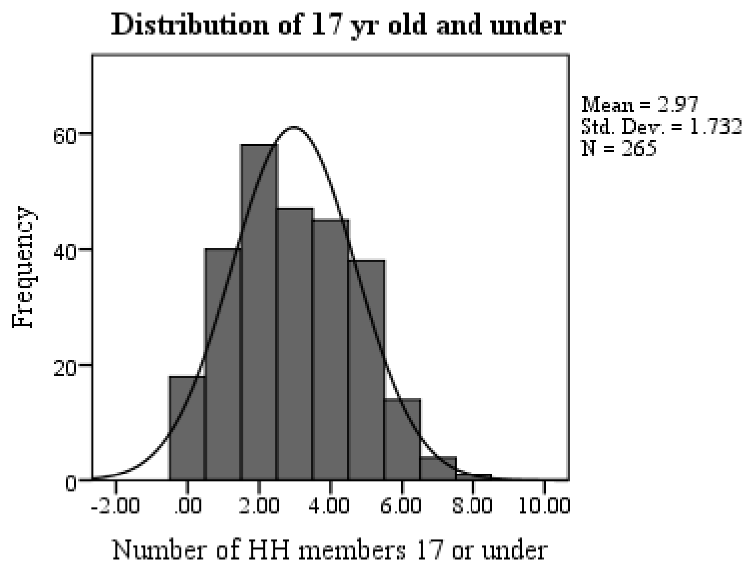


Figure 4.26. Histogram demonstrating the distribution of children of 17 years old and under (n=265).

There were on average 2.97 (SD=1.732, median 3) children of 17yrs and under in each HH, ranging between min. 0 and max. 8 (Figure 4.26).

Data followed normal distribution with no major outliers.

4.2.5 Education

Education levels among adult (18yrs and older) male and female members of the HHs were investigated. Men were on average more educated than women, with a higher proportion of secondary and higher education (Table 4.2 and Table 4.3).

Education (Male)				
		Frequency	Percent	Cumulative Percent
Valid	Primary	152	57.4	57.4
	Secondary	34	12.8	70.2
	Higher	15	5.7	75.8
	No completed education	46	17.4	93.2
	N/A	18	6.8	100.0
	Total	265	100.0	

Table 4.2. Education levels among adult male HH members (n=265).

Education (Female)				
		Frequency	Percent	Cumulative Percent
Valid	Primary	153	57.7	57.7
	Secondary	21	7.9	65.7
	Higher	6	2.3	67.9
	No completed education	79	29.8	97.7
	N/A	6	2.3	100.0
	Total	265	100.0	

Table 4.3. Education levels among adult female HH members (n=265).

Only 2.3% of adult females in the participating HHs completed higher education vs 5.7% male HH members. Completion of primary education was comparable between the two groups (57.4% among men and 57.7% among women). Almost 30% of females had no completed education compared to 17.4% among males. Not applicable (N/A) in the above tables signifies no adult HH members of either gender in the HH.

4.2.6 Occupation

The most common profession among both male and female HH members in participating HHs was a farmer (similarly as in the case of questions about education, HH members who were the survey respondents were asked about both the profession of adult female and adult male profession). Farming is often done for self-subsistence rather than for income (generating profit) and HH members tend to have other professions in parallel (either themselves or collectively among other adults in the HH). 56.5% of men and 82.6% of women were farmers. 9.8% of men and 5.6% of women were traders (mostly trading produce grown as part of their farming). Among men, the other most common professions were: construction worker (6.8%), teacher (5.3%), driver (4.7%) and carpenter (1.5%). Among women, the other most common professions were fewer, and included teachers (3%) and tailors (2.3%). Only two men and one woman among the participating HHs were reported as business owners.

Unemployment (recorded as 'no job') was reported for 3 women vs zero men. This might be due to the lack of validation of whether or not farming was as income generating activity or not. Previously, self-subsistence farmers would be counted as employed in the GoR Labour Force Survey (LFS), however, that has changed in the last few years to adhere to the international standards and self-subsistence foodstuff producers are now categorised as unemployed (National Institute of Statistics of Rwanda (NISR), 2018). In the 2016 LFS (NISR, 2016a) the unemployment rate stood at 18.8% according to the new measurements, and at 5.3% if counting self-subsistence foodstuff producers as employed. Unemployment rate among women was higher than among men (22.7% and 15.7% respectively) and overall higher in the rural areas than urban (19.8% and 16.4% respectively).

4.2.7 Distance from the grid

Survey households were located mostly in rural areas of North-Western Rwanda. On average, they were 36.47 minutes (s=45.19, median 25) (walking) away from the nearest gridline with a large range of min. 0 minutes and max. 300 minutes (5 hours). Figure 4.27 shows the distribution of distances from the grid among participating HHs.

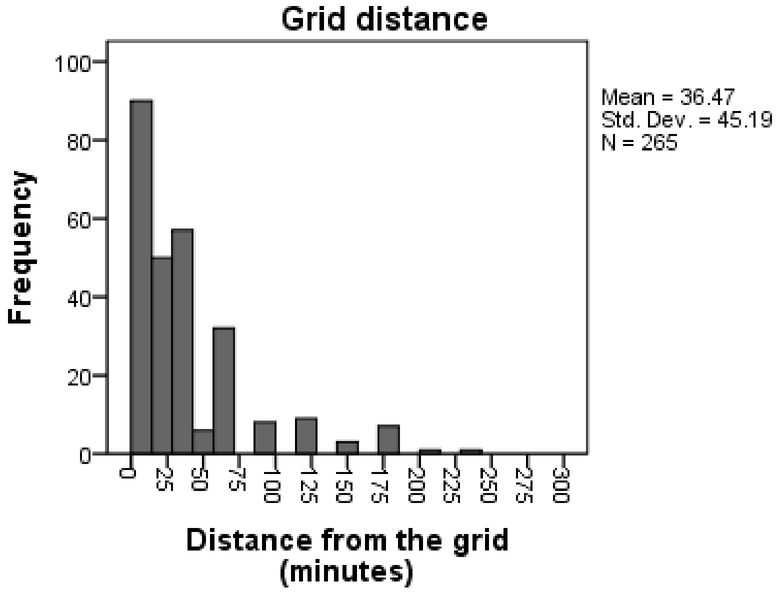


Figure 4.27. Histogram demonstrating distance from the grid (in minutes walking) among survey HHs (n=265).

67 HHs (or 25%) were within a 5-minute walk and less from the nearest gridline, with as many as 17 (or 6.4%) located right 'under the grid', meaning the gridline was in the immediate proximity to their house. Nearly a third of all HHs (30.9%) were 30 minutes walking and more away from the grid. 5 respondents reported their HHs had already been connected to the grid. The expressed likelihood of connecting to the grid network was low, as shown in the Figure 4.28 below.

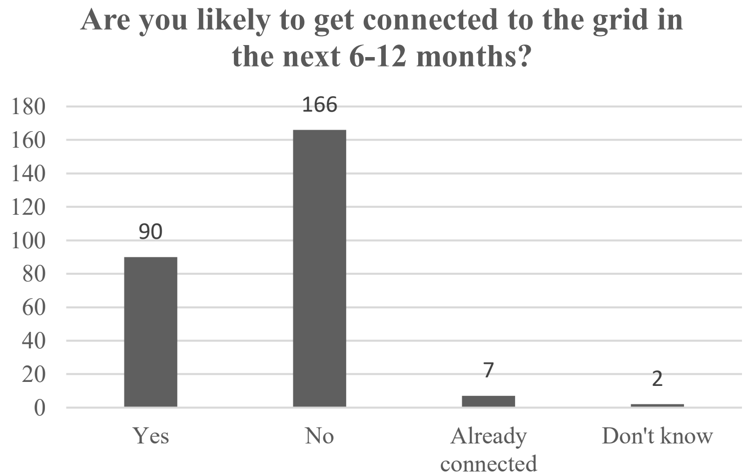


Figure 4.28. A bar charts showing the number of participating HHs (n=265) who are likely or not likely to get connected to the grid network and the number of HHs already connected.

63.4% of survey respondents said there was no likelihood of getting connected to the grid network in the near future, defined as the next 6-12 months, while 34% said that they were likely to get connected. This finding was consistent across FGs where customers reported little to no likelihood of accessing the grid. In all cases, the main reasons were: no plans for grid extensions to the village, inability to access the nearby grid due to the absence of transformers, unwillingness to connect due to preferences for off-grid solutions, and the cost of grid connection which is prohibitively high ($1000/connection). Subsidies are available to HHs unable to afford the full cost, however, even with a subsidy as high as $940, many HHs are incapable of making the upfront payment of $60 (SI10).

All those survey, FGs and PPWs participants who were connected to the grid would either stop using the grid, mainly due to its unreliability (frequent blackouts), fear of electrocution or inability to afford to pay for electricity consumption, or use the grid in parallel with the SSHS, which they used as a complementary energy source. There were three FGs participants who had switched from the grid to the SSHS completely, meaning they were no longer connected to the grid. More on perceptions of and aspirations to connect to the grid is discussed in section 5.3.4.

4.3 Energy use

Energy sources and services had been used among all study participants even before the adoption of a SSHS. In the following section the pre-adoption context of energy use in the daily lives of study participants is presented. That includes the sources and energy services they used to resort to, i.e. those that were available to them, and the advantages and challenges associated with them. Following on, motivations for the adoption of an off-grid solar system are discussed. These motivations arose at the time when HHs were relying on sources other than a SSHS and therefore make up a part of the contextual domain pre-SSHS adoption. After analysing those motivations, a general discussion follows, paving way to the exploration of the personal domain, where the reality of energy use among SHSSs users pre-adoption by comparing the pre- and post-adoption experiences of utilising energy in the HH is captured.

4.3.1 Energy use pre-adoption

All HHs used to rely on a combination of energy sources and energy services available to them in the area of their residency. Those sources enabled services such as lighting, mobile phone charging, access to information and entertainment (through radios) and cooking, as well as the ability to perform other activities such as ironing. The key determinants of which sources HHs would rely on were affordability and availability (can the source/fuel be found in a relative proximity?), although the latter would not always be achievable and HH members would have to travel to the nearest trade centre(s) (whether in a nearby village or town, on foot or by public transport, if able to afford it) to purchase the source/fuel or get access to the sought service. For example, charcoal is a desirable cooking fuel but it is not always available in the immediate vicinity, and mobile phone charging stations are not always present in villages which requires going to the nearest town to have a phone charged.

An average cost of the most common fuels used is shown in Table 4.4. An average cost of using public transport (most commonly a moto ride) if there is a long distance to be covered and one can afford to pay is included. The longevity of these fuels would vary depending on the intensity of use, size of HH, and the level of efficiency of use, especially in the case of cooking where improved cook stoves can generate more energy from the available fuel than traditional, non-energy efficient cooking methods.

Energy Use (prior to SSHS)	Average Cost (RWF)
Lighting (candles)	50 per candle (lasts approx. 1 day)
Lighting or cooking (kerosene)	1000 per litre. (lasts 1/3 of a month at 4hrs of use per day)
Lighting (C-type batteries for torches)	400 per 2 batteries (last 5 days at 4hrs of use per day)
Cooking (charcoal)	500[28][29] (small basket)
Cooking (fire wood)	Free[30] OR approx. 3500/month
Mobile phone charging	100 per charge (required daily or once every two days)
Radio (AA-type batteries)	100 per 2 batteries (last approx. 24hrs of continuous use)
Journey to get to mobile phone charging	500-1000 return trip

Table 4.4. Average prices of lighting and cooking sources, and transport costs. Adopted from Bisaga et al. (2017).

[28] Assuming an average family size of 6, a small basket of charcoal would last for approx. 2 days.
[29] Charcoal prices went up by as much as 100% at the start of 2017. A small basket would now be RWF1000. However, at the time of data collection the price shown in the table was the current one.
[30] If self-collected, predominantly done in dry season. Rainy season makes fire wood collection challenging.

Below is a breakdown of all energy sources which used to be relied on in the HHs prior to purchasing a SSHS. There is a clear indication that energy stacking behaviour was common as every HH used to rely on more than one energy source, which is associated with different activities for which different fuels used to be used. This is demonstrated in Figure 4.29.

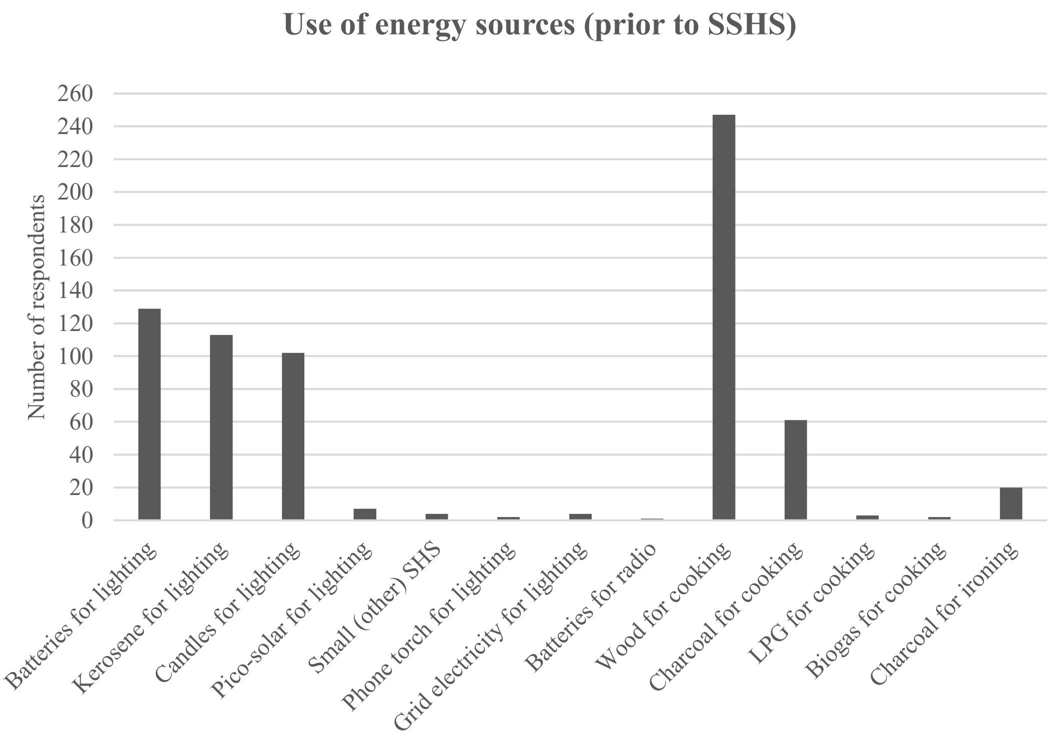


Figure 4.29. Use of energy sources prior to purchasing a SSHS (n=265, total responses=695).

Batteries (for torches), kerosene and candles were the most common light sources used before a SSHS was adopted. Other off-grid solar solutions included a pico-solar lamp (solar lantern) and other SHSs (other than those offered by BBOXX). Wood was most commonly used for cooking (93.2% of survey respondents used it), which was consistent with the estimated national rates of 93% of wood (biomass) use in rural areas (WB, 2016). It was followed by charcoal (23%), which on the national scale was also the second most commonly used cooking fuel (ibid.). These results corroborated findings from FG(1-5) and PPWs where previous energy sources were also discussed.

SSHSs currently do not support cooking therefore, as will be shown in subsequent sections, having a SSHS does not impact on the range of fuels used for cooking. It might impact on them indirectly in that potential savings from having a SSHS (e.g.

from not having to purchase lighting fuels or paying for mobile phone charging) can be channelled into different (improved) cooking fuels, however, there is not enough evidence gathered in the course of this study to support this hypothesis.

The above-listed sources, or fuels, are the ones that used to be utilised internally in the HHs. They provided the ability to perform certain activities, such as cooking, ironing, using light to enable performance of chores, reading etc. However, some energy services could not be satisfied with the use of those sources. The most important one is mobile phone charging which is critical as there is at least one mobile phone per HH (in order to purchase a BBOXX system, customers have to provide at least one mobile phone number). Charging phones at one's home would only be possible for those who were connected to the grid (9 out of 265 reported having a grid connection prior to purchasing a SSHS) or other SHSs. Pico-solar lamps occasionally also provide phone charging, but it is not a universal feature among those devices. For all others, phone charging stations or charging phones at friends' or family (if such an option was available) were the only choices. Charging phones externally also required walking often long distances, or paying for transport, and a relatively high time commitment as not only one has to walk to wherever the phone gets charged, but he or she also needs to wait for the phone battery to be fully charged. As one FG1(5) participant noted:

> "I [bought the system because] I wanted to charge my phone because I was fed up to go off to where the grid is." (Male participant, FG1(5), Gakoro)

Another inconvenience mentioned by study participants was the risk of having one's phone battery stolen or replaced with a faulty/degraded one, or not having the phone fully charged while paying the full cost. Drained battery in a phone would often mean a loss of business opportunities due to unreachability. As explained by one participant (PPW2):

> "[I bought the system] to be able to charge my phones. I was sometimes unable to make money, because sometimes people would call me to give a job and they were unable to reach me." (Male participant, PPW2, Nyamata)

Use of traditional lighting sources (candles, kerosene) was also associated with risks, mainly of sparking fire in the house and/or getting burnt, and being affected by the smoke, with eye sight and respiratory problems of highest concern to the study participants. A particular worry was expressed for children, if there were any in the HH. Stepping outside in the dark had been a worry for inhabitants of areas where there is no outdoor lighting around. A woman living in a remote village with no grid extension gave an example:

> "I used to use kerosene and I could not go to the toilet or even outside in the evening, I was scared, but now I have put lights outside and inside the house, I am no longer afraid to go out." (Female participant, PPW20, Nyanza)

Light torches, powered by batteries, have been gaining popularity due to providing a cleaner source of light at a relatively competitive price. However, if used heavily, they do not last very long, and batteries need to be replaced frequently. A grid-connected PPW19 participant (the female household head) mentioned, when justifying why she and her husband decided to purchase a SHS despite having grid access at their home:

> "I bought the system because here when it rains especially with the thunderstorms, the power goes off and we need to buy torches. I normally don't buy candles because of the children. So, I always had to use many batteries for all the rooms which is so expensive, and the batteries don't even last for long but now when the electricity from the grid goes off the system is always on." (Female participant, PPW19, Nyanza)

As demonstrated in Figure 4.29, typically more than one lighting source would be used in a HH. Fetching and using those lighting sources would also come with a number of inconveniences and challenges, among others: the need to either buy them in bulk or make regular trips to purchase them (if heavily used, all of them run out fast and need to be regularly restocked); the inability to purchase them at certain times, e.g. if one runs out of lighting sources late in the evening, it proves challenging to buy more as it is either too late for any shops to be open or too dark outside to make the trip, which is also seen as dangerous, as a result one spends the rest of the evening in darkness; an insufficient amount of light provided, especially if only one torch or one kerosene lamp are available to HH members. As stressed by PPW13 participant, the head of the household:

> "I wanted to reduce expenses on other energy sources which we were using [battery-powered torches] and which could not satisfy everyone". (Female participant, PPW13, Gicumbi)

The inconvenience of having to hold the torch or the lamp or place them so that they shed light onto wherever it is needed, while performing various activities, was particularly stressed in the case of women cooking: they would either hold the torch/lamp/lantern or a candle in one hand over the cooking area in order to see the utensils or place them within that area or occasionally hang them up to free both hands. In some instances, women reported holding a torch in their mouth while cooking, for example in the case of PPW2 participant's wife who, as he said:

> "[…] used to face another big challenge. Whenever we could afford a torch, my wife would do some activities holding that torch in her mouth, for example to cook, and she used to tell me that she was feeling pain and we were always wondering how we would explain to the doctors about her illness. I would also wonder how this was going to end. But now she no longer holds a torch in her mouth and she tells me that she no longer feels pain". (Male participant, PPW2, Nyamata)

In other instances, women said they would also have to hold their children up in their arms while cooking as they did not want them to play or run around in darkness without supervision. A female PPW1 participant admitted that:

> "[…] before I would cook holding my child on my back and also holding the other one in my arm so that they don't step into animals because in this region we have snakes which could bite our children because they could not see them". (Female participant, PPW1, Nyamata)

Having no or a poor lighting source would also make simple activities difficult, like moving around the house at night (risk of tripping over and/or hurting oneself with HH objects in the darkness), doing other chores around the house, dressing, bathing, perform work activities which require lighting, reading, which could be straining over a dim or polluting light source, or even socialising with family, whether by gathering together or sharing a meal in a bright environment. For customers running businesses (e.g. shops, bars, barber shops, cafes etc.), having a reliable source of light was also very important and if they did not have access to the grid network, their activities could get affected by having poor or no lighting. One bar-owner described his experience saying:

> "I wanted to use it [the system] in my bar, because before I was using candles and it was hard to serve my clients because I used to have many clients. Sometimes I would serve them in the darkness."
> (Male participant, PPW12, Gicumbi)

Other services, or activities, which require access to energy (mainly access to electricity) are entertainment. The most common forms are watching TV and listening to music or a radio. With no access to electricity, people would typically listen to music and radio (including for news) on their phones, if they own one. To watch a TV, they would either go to a bar with a TV or to someone in the village or the neighbourhood who owns a TV and is willing to have others come watch it (this can be either at a charge or free of charge). Football is a very popular sport in Rwanda and has many followers, with football games widely watched across the country, predominantly be men, who tend to gather at local bars to watch football matches. Many female participants mentioned that men in the family would often stay late at a bar only to watch TV, frequently a football match. Children would wander off to find places with a good source of light and/or a TV to either play, watch TV, pass time or study. In families with children, it was expressed as one of the concerns as parents would not be able to watch over the children's activities and would sometimes be unable to locate them.

For those who used to rely on grid electricity prior to purchasing a SSHS, some of whom continue to do so, one of the disadvantages of those connections was a risk of electrocution. Children were seen as the most vulnerable. Another one was short electrical circuits, at times of power surges, which were seen as posing danger to both the appliances plugged in to power and to the HH members. Another grid-connected customer explained:

> "I can't use on-grid system in my room because there is risk of electrocution. But I realised that off-grid system is safe and there is no risk of fire. Whatever I can plug into the system I feel safe, I can't get

> burnt or electrocuted. It's not similar to on-grid because their sockets can have the short electrical circuit. For example, that switch *(pointing to a burnt switch)* got a short electrical circuit and the only thing I did was to just turn on the switch." (Male participant, PPW15, Gasiza)

Unreliability of the grid connections and the regular blackouts were flagged as a big challenge, as they would mean having to seek other energy sources. The same customer provided an example:

> "I am also connected to on-grid. The electricity can go off for a long period of time. As you can see our District is located in remote area and there is also rain. Therefore, I thought that I could maybe look for a solar lighting company and that's when some agents came to advertise about the system." (Male participant, PPW15, Gasiza)

These aspects of connecting to the grid network were among the reasons not to join the grid network mentioned by users of SSHSs when discussing questions around aspirations for the future (see section 5.3.4).

This section aimed to provide a synopsis of the energy use reality of study participants prior to them adopting a SSHS. It sets the context for the following sections. First, the motivations and aspirations the participants had which contributed to the decision about purchasing an off-grid solar system, and subsequently and in-depth exploration of the current energy use behaviour among users of SSHSs, and their needs and aspirations.

4.3.2 Motivations

The key reasons for purchasing a SHS are reflective of the challenges faced prior to doing so, identified in the previous section. The most common reasons for deciding to purchase an off-grid solar system among survey participants are presented in Figure 4.30 below.

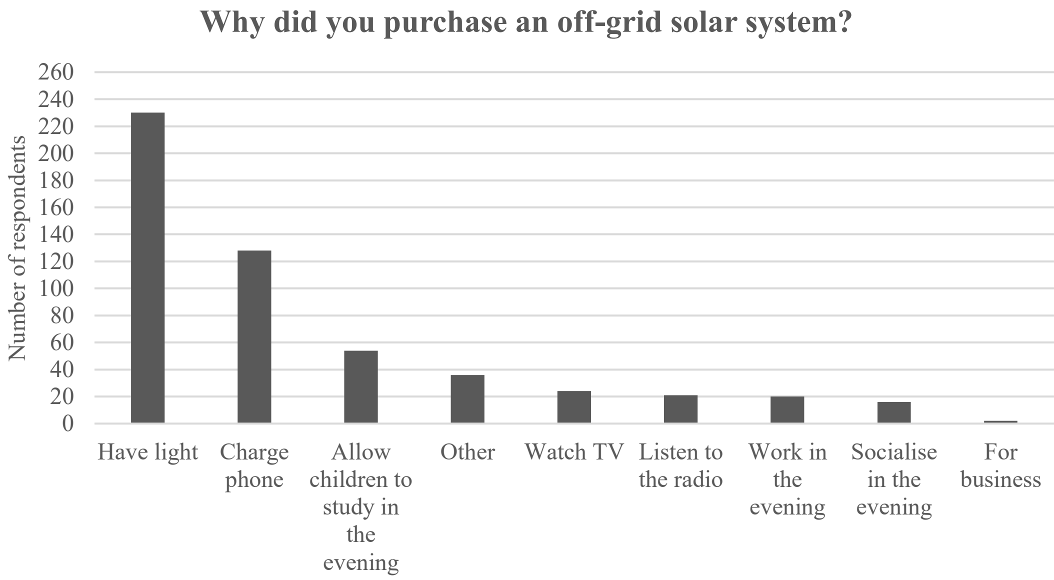


Figure 4.30. Reasons for purchasing an off-grid solar system among survey participants (n=265, total responses=531).

'Other' reasons included the desire to reduce the use of other sources and to reduce the expenditure on them. 3 (out of 9) of the participants who had a grid connection said it was the unreliability of the grid that was also a reason[31]. No prospect of connecting to the grid in the foreseeable future was another one.

Comparing male and female owners' reasons for purchasing a SHS, it can be seen that there are only few differences (Figure 4.31).

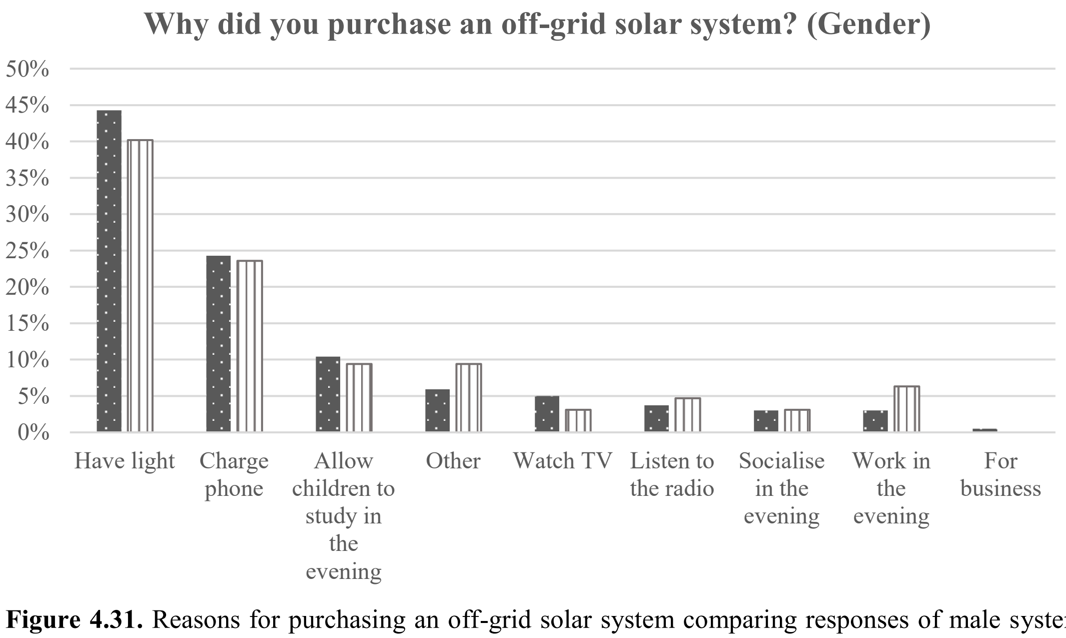


Figure 4.31. Reasons for purchasing an off-grid solar system comparing responses of male system owners (n=203) and female system owners (n=62).

[31] For a clarification of different numbers of previously grid-connected customers, please see p.227.

The top three reasons are the same: having light, being able to charge a phone, and allowing children to study in the evening. ‘Other’ in both groups mainly focused on reducing the use of and expenditure on other sources, more often women than men. Listening to a radio and being able to work in the evening was also more prevalent among women than men, although the numbers are relatively low in those responses. However, for women who stay at home throughout the day, listening to a radio is a form of entertainment and homemaking female participants of FGs and PPWs have shared it in discussions as well. The ability to work in the evening means more flexibility of chores throughout the day and evening which might carry more importance for women than men as they are the ones predominantly in charge of household chores.

An examination of the reasons for purchasing an off-grid solar system between three poverty groups (LLP, ILP and HLP) (Figure 4.32) shows little difference in the main reasons, with ‘Other’ reasons congruent with those of the entire sample.

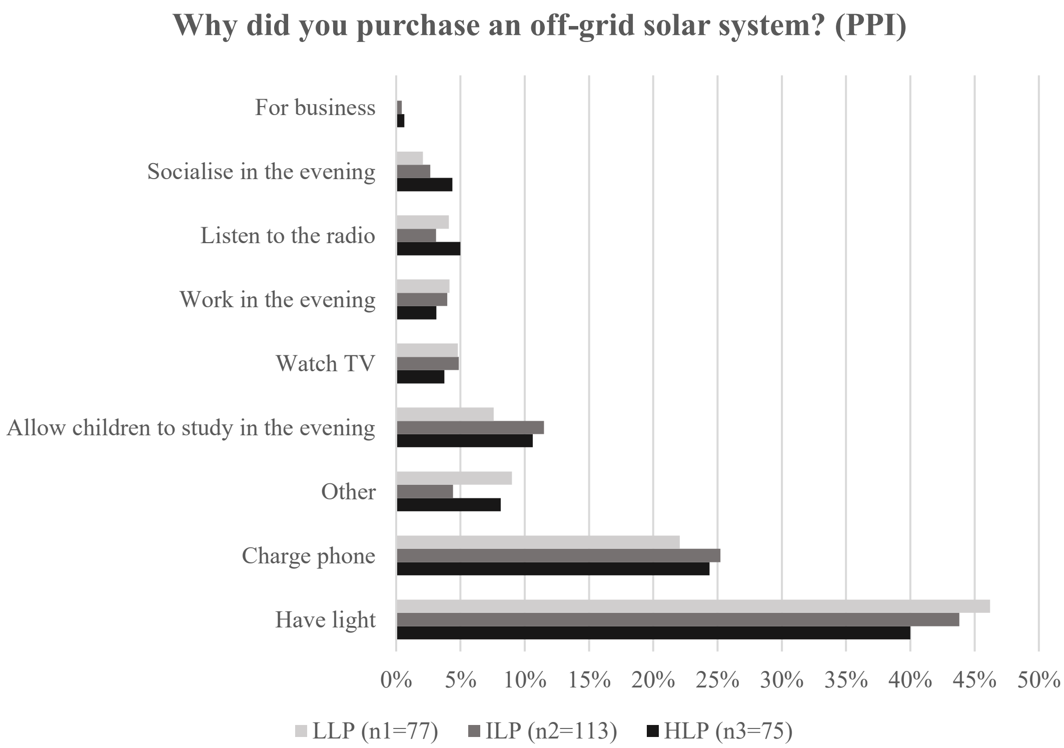


Figure 4.32. Reasons for purchasing an off-grid solar system comparing responses of LLP (n1=77), ILP (n2=113) and HLP (n3=75) groups of respondents.

However, an inspection of those reasons according to age groups (Figure 4.33) reveals that wanting to be able to charge a phone (or phones) was more common among two lower age groups (<32 and 32-38) than the upper two (39-47 and 48+), with the former two declaring it as a key reason in 30% of their responses vs less than 20% in the case of the latter two. The reverse was noticed for allowing children to study in the evening as a reason to purchase a system. The two upper age groups chose it as one of the key reasons 13% (48+) and 16% (38-47) vs 7% (32-38) and 3% (<32).

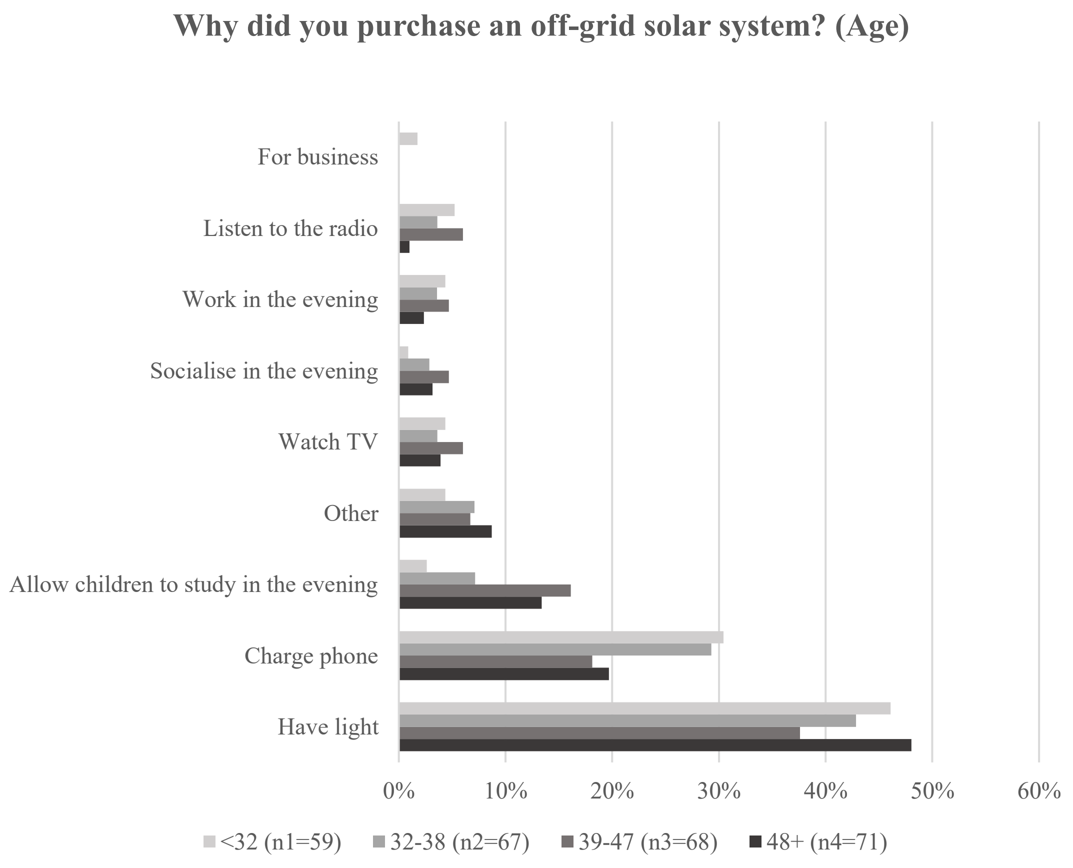


Figure 4.33. Reasons for purchasing an off-grid solar system comparing responses of male system owners (n=203) and female system owners (n=62).

Mobile phones have become a ubiquitous technology, also in Rwanda. Their heavy use and therefore the frequent need to charge them is particularly present among the younger part of the population who rely on mobile phones for personal and professional communication. Phone charging is therefore expected to be a significant need among the two lower age groups who are not only all at the working age but also more likely to have grown up with more exposure to mobile phones in their youth and/or early adulthood. The more common response of allowing children to study in the evening among the upper two age groups points to their children (in families where there are any) being at the school age, whereas children in the lower two age groups (where there are any) might still be too young to attend school and therefore do not require evening time for studying.

A separate question was asked about motivations for choosing a BBOXX SSHS (Figure 4.34). Its goal was to understand what the key motivational factors were for choosing this specific provider. However, the most common response was ‘to get rid of darkness’ which is the equivalent of the above-listed reason ‘to have light’. Even though it does not specifically relate to the provider, it emphasises the importance of wanting to have light in the house.

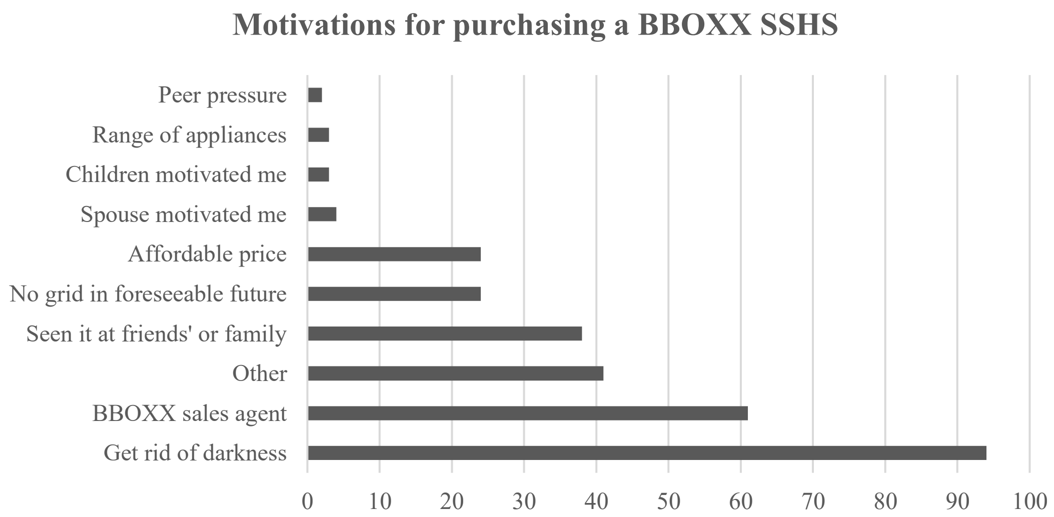


Figure 4.34. Key motivations for choosing a BBOXX SSHS among survey participants (n=265, total responses=294).

The motivations question yielded somewhat more pronounced differences between male and female system owners, as is demonstrated in Figure 4.35 below.

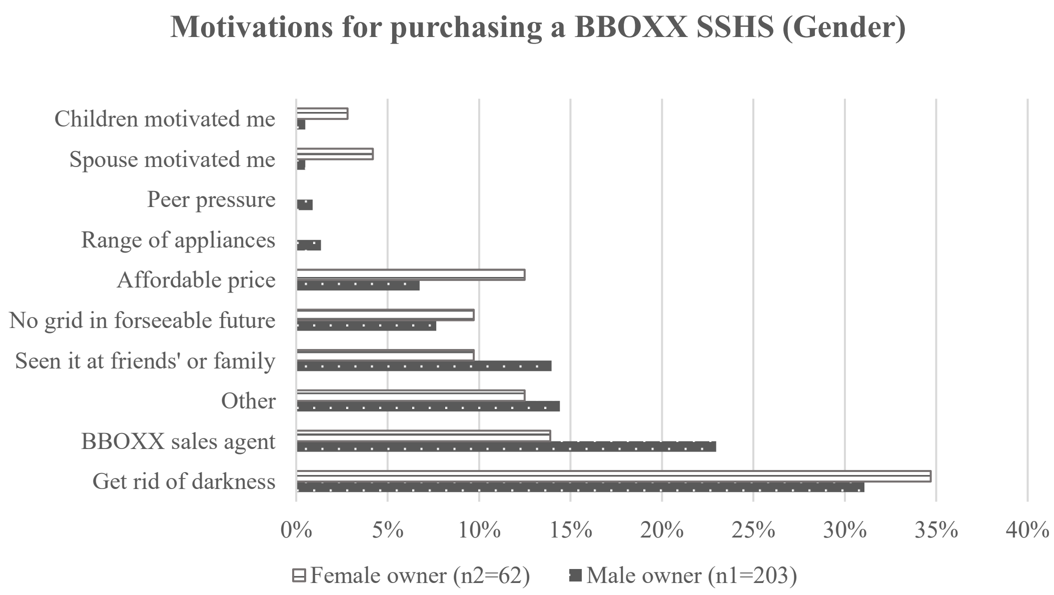


Figure 4.35. Motivations for choosing a BBOXX SSHS comparing responses of different age groups: <32 (n1=59), 32-38 (n2=67), 39-47 (n3=68) and 48+ (n4=71).

More women were motivated by their spouses and children than men for whom it was extremely rare. Nearly twice as many women as men found affordability to be an important motivation whereas BBOXX sales agents motivated a considerably higher proportion of male than female system owners. 'Other' motivations (overall) included radio advertisements (8.3% of all participants), with company representatives at BBOXX's shops being mentioned less frequently and marketing events and cell meetings acknowledged in only a few responses. This was similar between both men and women. Prior empirical experience of seeing a SHS at somebody else's house or any other establishment with an installed SHS played an important role in taking the decision to purchase one, however, more so for men than women. One (male) FG1(2) participant said:

> "When I visited to my neighbour, and after realising how lights in the evening are, watch the TV, and I was inspired to buy the product as well". (Male participant, FG1(2), Bigogwe)

Another participant of FG1(5) shared a similar experience:

> "I visited a friend after finding out how he lights his house. I was motivated to buy the appliances as well because I wanted to light up my house!" (Male participant, FG1(5), Gakoro)

It would be hardly or not possible at all for those who lived in areas with a very low rate of SHSs penetration (at the time prior to data collection, i.e. prior to adopting a SSHS). However, for those in areas where SHSs had reached at least a few community members, investigating the product ahead of purchasing it was preferred and frequently mentioned across survey, FGs and PPWs participants.

Deconstructing the data according to poverty levels (Figure 4.36) sheds additional light on which users were motivated by seeing a SSHS somewhere else before purchasing one themselves. In the LLP group, as many as 20% of customers had been motivated that way as opposed to the ILP users among whom 12% selected it as a motivation and 7% among the HLP group. Similarly, sales agents were more commonly a motivation among LLP and ILP groups (23% and 24% respectively) vs 13% in the case of HPL respondents. This suggests that users who are least likely to be living in poverty might be getting more exposure to others who have adopted similar technologies and that sales agents, who often come from the communities where they operate and are familiar with their members, target the better off HHs (LLP and ILP).

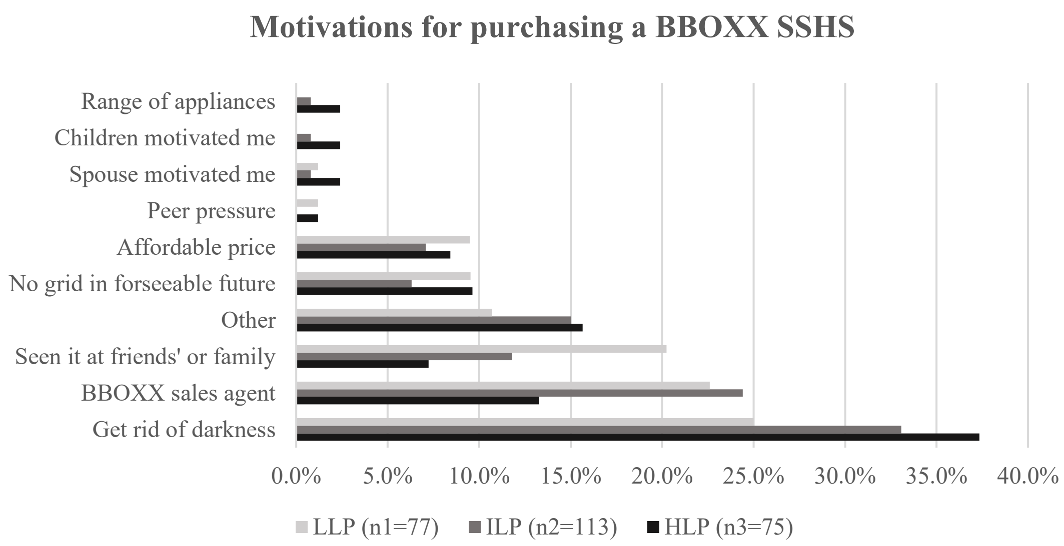


Figure 4.36. Motivations for choosing a BBOXX SSHS comparing responses of LLP (n1=77), ILP (n2=113) and HLP (n3=75) groups of respondents.

Among HLP respondents, a radio advertisement was the most common 'other' motivation for purchasing a system, with two respondents indicating being motivated at a BBOXX shop directly, one at a marketing event, one found the payment method motivational, and one wanted to get lighting for a business. Among ILP and LLP group respondents, radio advertisements were also the most common 'other' motivations, followed by exposure to the systems directly at a shop, marketing events and a few pointing out cell meetings (which are part of the monthly *umuganda* scheme, mentioned in section 4.1.2.2) at the time when they learnt about off-grid solar and decided to adopt a system.

The below Figure 4.37 demonstrates that more customers in the upper two age brackets had been motivated by a sales agent than those in the lower two. Affordable price was more commonly a motivation for the 48+ age group than in the other three whereas no prospects of getting a grid connection in the near future motivated more younger respondents, particularly in the <32 age bracket.

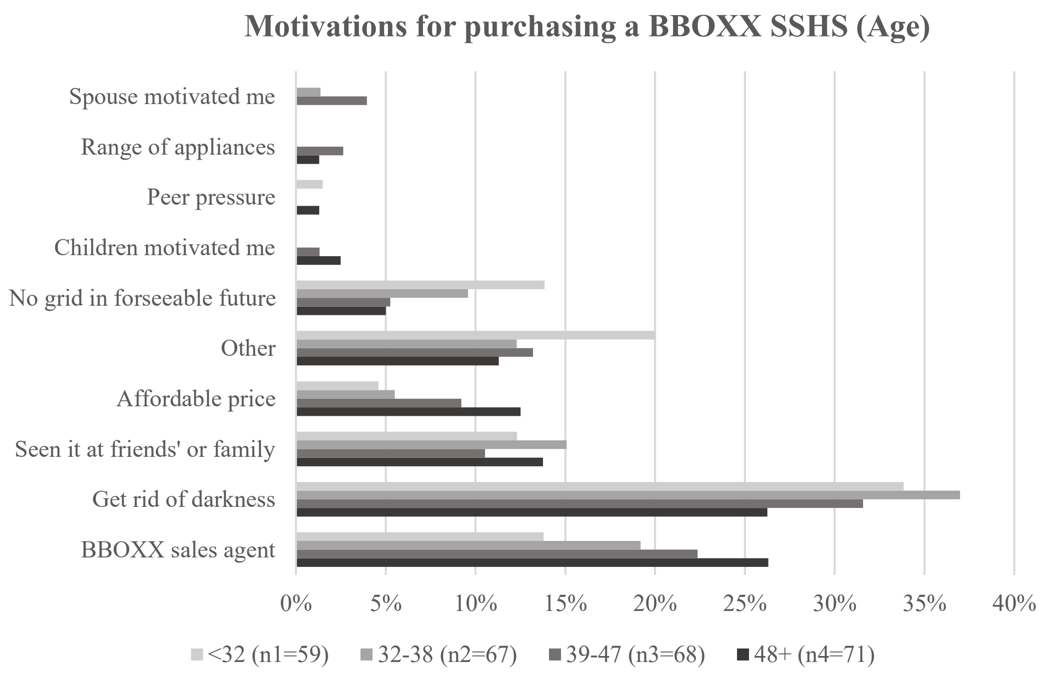


Figure 4.37. Motivations for choosing a BBOXX SSHS comparing responses of different age groups: <32 (n1=59), 32-38 (n2=67), 39-47 (n3=68) and 48+ (n4=71).

Awareness of off-grid solar systems, perceptions of them and familiarity with other providers will be discussed in Chapter 5.

4.4 Chapter summary and discussion

This chapter has explored the contextual domain of energy use, including the physical environment, the policy and regulatory environment, which also includes existing frameworks incorporating energy access targets in Rwanda, and the household characteristics which encompass details such as age, composition, poverty levels and education to draft a profile of SSHSs adopters in the North-West (NW) of the country. The analysis of the energy use in the HH pre-adoption of a SSHS adds to the contextual domain by demonstrating how and what energy fuels used to be used in the HH prior to adopting a solar system, giving an indication of the HHs' capabilities regarding energy use and choices, primarily driven by factors such as availability, accessibility and affordability.

The physical environment of the NW is a challenging one, with a hilly terrain that makes accessibility challenging, particularly for more remote towns and villages as roads are not paved and they can become unpassable in the rainy season. The lower levels of irradiation in that region and the higher number of rainy days throughout the year have an implication for solar solutions which rely on sufficient and consistent levels of irradiation for proper functioning. Additionally, the mountainous landscape impedes on the swift extension of gridlines as the cost of building the network on such challenging land is costlier than on flat terrain. As a result, the availability of and accessibility to grid power is limited or currently non-existent, and the more remote areas will not be reached in the near future, eliminating (or considerably postponing) that option for the unelectrified HHs. According to Rwanda Utilities Regulatory Authority (RURA) (2018), the number of on-grid subscribers increased from the 3rd to 4th quarter of last year (2017) from 683,817 to 718,311 (an increase of 5%), with 29% of customers connected to the grid located in the City of Kigali, 22% in the Eastern Province, 20% in the Western Province, 16% in the Southern Province and 13% in the Northern Province. In the same time period, off-grid customer numbers went up from 142,194 to 162,154 (an increase of over 12%). Given the lowest rate of grid connections in the Northern Province, off-grid solutions in that region will be indispensable for the electrification efforts and for the achievement of the ambitious electrification targets.

The discussed electrification policy and regulatory framework, which incorporates off-grid solutions, is a critical component of extending energy access to those currently still relying on candles, kerosene lanterns and battery-powered torches for light, and on externally offered services, such as mobile phone charging. Not only is the explicit inclusion of off-grid solutions, including SHSs, in the Rural Electrification Strategy critical for a successful creation of an off-grid solar market, but so are the existing frameworks which are not exclusively energy-focused, but which incorporate access to energy as one of their foci, such as the discussed *imihigo*. The performance targets at the top administrative levels ensure that there is a concerted effort among various stakeholders to work towards achieving them. This includes efforts to electrify 100% of the population by 2024. At the lower administrative levels, such as cells, sectors and districts, they safeguard the presence of access targets in the timely execution of projects focussed on electrification, be it grid or off-grid, as explicitly stated in the MININFRA's and EDCL-REG's own *imihigo.* Most importantly, however, performance targets at the HH level are aspirational, meaning they reflect what the aspirations of the given HH are for the coming year and what goals or improvements they want to achieve. They are based on actual, physical and economic, capabilities estimated by HH members (mostly the HH head and the spouse) which drive the choice of targets, both in nature (what targets in what areas demarcated by the three pillars are selected) and number (how many are adopted), for any given year. This framework delineates the contextual domain in which HHs and their members navigate their daily lives (with other frameworks also in place, whether set by themselves, their communities or the government) and thus links to the personal domain, which is discussed in the next chapter. It brings together needs, aspirations and motivations, and the willingness to excel and develop, through access to better services, such as energy, better work or school performance, etc. However, in the course of the research, it has been discovered that the *imihigo* framework is used more in some regions vs others. E.g. study participants in the Northern Province reported using the framework and being accountable for their commitments more than in the Eastern and Southern Provinces, based on what was declared by PPWs participants. Although not systematic in regard to the application and execution of the framework, this research points to various levels of implementation and obeying of the performance targets framework across different regions. Regardless of whether universally adopted or not, understanding the impact of village, sector and district level *imihigo* on the HH-level *imihigo* can prove beneficial in better targeting those whose best and most appropriate way of getting electrified (at least in the foreseeable future) is via off-grid solutions and informing private sector providers on where such *imihigo* have been adopted at cell and sector levels. Community engagement through means such as *umuganda*, are important channels for discussion, awareness-raising and dissemination, and can also be utilised to the advantage of both public and private providers of energy services.

The disproportionate numbers of men in system ownership stem from the more traditional gender roles in the rural areas of Rwanda, where women tend to be the homemakers in charge of the HH and associated chores, and men the breadwinners in charge of decision-making, even though consultation with spouses is not uncommon. As a result, it is the men whose details are recorded at the time of purchase of (or subscription to) the energy services. The majority male ownership has implications for gender mainstreaming in energy access as consultation with customers by default largely incorporates views of the men, seeing how they are the ones contacted, and women's voices are limited, unless actively sought through deliberate targeting. In the case of this research, reaching women proved to be easier in in-HH interviews as they are the ones who are present at home during the day more often than men. The gender aspect of energy use is an important one to understand the distinct needs and aspirations of men and women, and the impact energy access has on women in particular, as will be further discussed in this section and in subsequent chapters.

Poverty likelihood measurement has shown that off-grid solutions are adopted by those very likely to be living in conditions of poverty (under the $2.50/day line), and those more well-off. The poverty profile determines the capabilities of the HH and the decision regarding not only energy access (including electricity and cooking fuels used), but also other services. It does not, however, determine the needs or aspirations, which can be shared among different groups regardless of their poverty profiles.

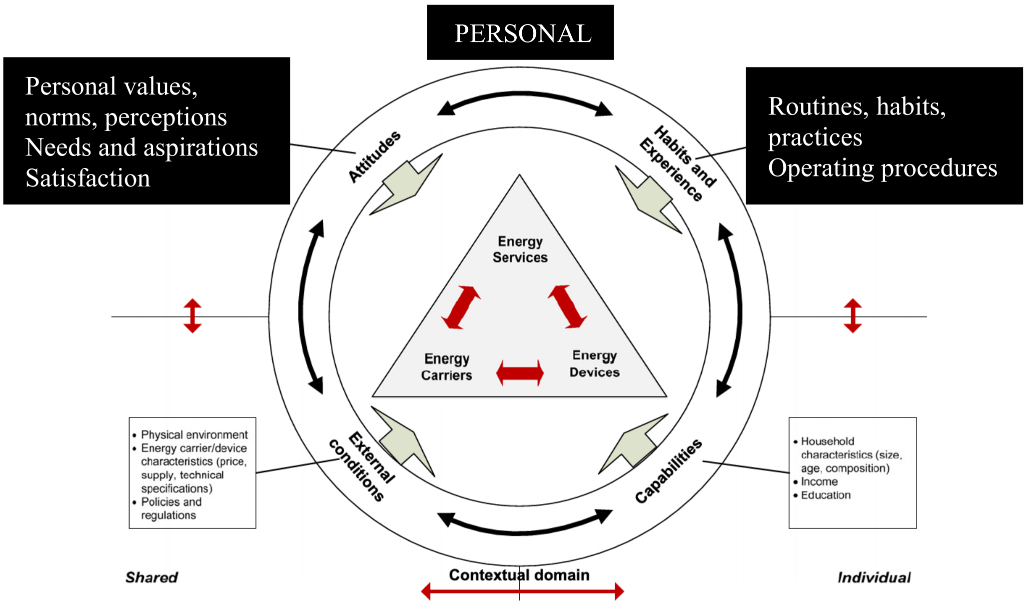
Regardless of poverty levels and occupation, all study participants had access to energy fuels in their HHs before deciding to adopt a SSHS, with candles, kerosene lanterns and battery-powered torches being the main sources of light and other energy services (such as mobile phone charging and access to a TV) sought externally, except for some instances of HHs which had previously had a grid connection or access to a smaller solar solution (such as a solar lantern), where those sources were used less and access to other services was available, although the unreliability of grid power could compromise them. Those sources also require financial capacities but offer the option of being purchased as and when necessary, without the need for regular payments (which is not the case for SSHSs offered by providers such as BBOXX). An analysis of sources used by unelectrified HHs and the amounts they spend on them has implications for the design and the tailoring of solutions which are superior yet still affordable to rural populations. As solar solutions become more ubiquitous, in a similar manner as battery-powered appliances did (such as light torches), it is also expected that more HHs will start moving up the solar product energy ladder (e.g. from a solar lantern to a SHS) that has been seen so far (Scott et al., 2016) which means that more people will be familiar with off-grid solar at the time of SHS adoption, something that has not been observed as a trend in this study. However, considering that Group 1 participants had adopted their systems before early 2015, Group 2 between mid- to late 2015, the number of HHs moving from pico-solar to SHSs which stood at less than 3% of survey respondents in mid-2016 would be expected to be higher. Familiarity and prior experience with small-scale solar in the community can boost trustworthiness of other off-grid solutions and make it easier to trigger interest and speed up adoption.

Lighting as a basic necessity has been seen as the key motivation to subscribe to off-grid solar energy services. Motivations directly link to needs and aspirations: motivations to adopt a SSHS stem from the need to rid one's HH from darkness, eliminate hazards associated with the use of candles and kerosene, create new opportunities, get services otherwise sourced externally, and improve the overall well-being of HH members. Motivations can also be influence by others outside of the HH, for example sales agents working for off-grid solar providers, other community members who have adopted similar solutions and can have the power to either promote or discourage adoption among other community members, or awareness campaigns such as those organised by the REC and marketing events organised by the providers themselves. Seeing a SSHS at someone's home or place of business is a common motivation especially among men and LLP HHs, who constitute groups with a higher chance of getting exposure to similar technologies adopted elsewhere. As shown earlier in this chapter, sales agents are more likely to target men and better-off groups (LLP and ILP) than women and HLP HHs as it increases the chance of making a sale due to men being predominantly decision-makers and lower poverty groups having more resources to invest in energy access. As the use of phones is ubiquitous and phones carry a lot value in terms of communication, whether personal or commercial (for work-related affairs), charging them can be laborious yet critical. Alleviating this issue is another important motivational factor for those who decide to purchase a SSHS, particularly in the younger age groups (between 20-40yrs old). For customers who have school-aged children the possibility of allowing them to study in the evening in improved conditions, without the smoke which can hurt their eyes and respiratory systems, is more motivational than for those who do not have children or children of school age.

As the analysis of energy fuels prior to system adoption has shown, a variety of energy sources are in use at any one time, proving that energy stacking is a common practice which continues post adoption. This has an implication for the HHs in terms of addressing the challenge of risks and disadvantages associated with smoke-producing lighting fuels (candles, kerosene lamps) given that smoke from cooking remains as firewood (or charcoal) continue to be used on a daily basis. It has particular ramifications for women who are the ones responsible for meal preparation and their exposure to smoke in cooking areas persists even if it gets eliminated in other parts of the house as a result of using a SSHS. Understanding gender dimensions, therefore, plays an important role in scaling up energy access. Daily practices can vary between men and women. One example of which is the above-mentioned responsibility for cooking, where having access to a clean cooking fuel as well as a reliable source of light can make a considerable impact on those performing cooking-related activities, making them easier and safer, and often faster with more energy-efficient fuels. Consequently, the gender-based roles and predispositions can drive motivations for both men and women, some of which are shared and others which differ. However, the agency often lies with the one who is in charge of HH decisions and finances, risking bias towards prioritising some needs over others. Pachauri & Rao (2013) argued for more evidence on both the within and outside the household factors which influence women's decision-making power regarding modern energy services adoption. They also stressed that disregarding gender inequalities "[…] can undermine the potential for transforming women's status and well-being" (p. 205).

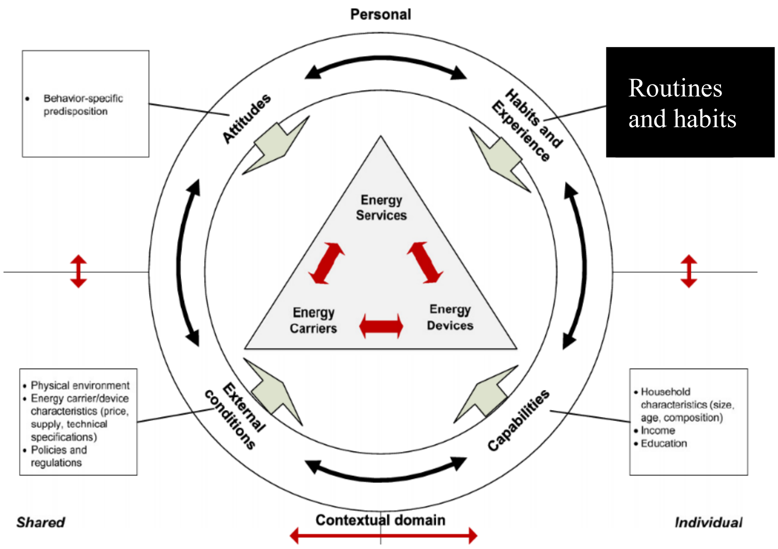
On-the-grid HHs are also among SSHSs users. Key motivations are lack of grid reliability (blackouts), unwillingness to have to rely on sources such as candles or torches for times of blackouts, safety (power surges and risk of electrocution are seen as main risks associated with having a grid connection) and having a substitute (less common) or a complementary energy source in the house. 6.4% reported living 'under the grid' (i.e. in the immediate proximity of the grid), and another 25% were within a 5-minute walk from it, confirming that it is not exclusively remote HHs located far from the grid line who adopt off-grid solar solutions but also HHs within the reach of the grid. The feasibility of and the need for such solutions therefore go beyond rural, remote areas only. Lenz et al. (2017), in their investigation of the Electricity Access Roll-Out Program (EARP) in Rwanda observed electricity consumption and uptake of appliances among HHs gaining connection to the grid network remain low even after a few years and question whether grid extensions are the most appropriate means of extending access modern energy while the alternatives (i.e. off-grid solutions) can be more cost-competitive, provide sufficient levels of power, and potentially better meet the willingness to pay of the transitioning HHs.

Chapter 5 Findings: Personal Domain



The personal domain of a household's energy use is where attitudes, habits and experiences are explored. The former include personal values, norms and perceptions, which in this study also cover energy needs and aspirations, and satisfaction with energy services, devices and carriers. The latter encompass the operating procedures which are standard for the individual and the HH, and the routines (or practices) built around energy use. Combined, the two spheres of the personal domain are also where the impact of using energy services is observed. This chapter thus probes the many aspects of everyday energy use among study participants and by doing so completes the full circle of what constitutes the Household Energy System, as defined by Kowsari & Zerriffi (2011), consequently drafting the interrelationships between the two domains (contextual and personal), the three dimensions of the energy system and the dynamics between them.

5.1 Habits and experience



"An in-depth study of the human dimension of energy use is a vital step for improving our understanding of household energy use in rural regions of developing countries" (Kowsari & Zerriffi, 2011: 7515). The following sections will explore this human element by looking at the habits and experiences associated with the use of SHSs in HHs in Rwanda's North-West and beyond by also bringing in the perspectives shared by the participants of PPWs (from both the North-West and other provinces). Both their literal and metaphorical lens was the camera which enabled them to depict, through photos, matters of energy use around their homes which were meaningful to them in a way that was much less structured than the surveys and FGs, and therefore unrestricted by the researcher's questions or pre-existing notions. This section will therefore continue to draw on both the quantitative and qualitative evidence collected during the study.

5.1.1 Operating procedures

Examining operating procedures allows to better grasp the where, the how, the who, the when and why of energy use at the HH level. It incorporates both the energy devices and services, as well as carriers.

5.1.1.1 Where?

In as many as 91% of the survey HHs the system[32] is placed in the bedroom. Among those, 68% said it was for safety reasons (Figure 5.1). Others pointed out convenience and the technician's suggestion as the reason for it being in bedroom, with a similar proportion of respondents saying they put it there to keep away from the children, so that they would not play with it. That was particularly the case for HHs with small children. Those who use the SSHS at their place of business keep it there, although in three instances the system was kept at the shop for convenience and was adjacent to the HH, which could suggest a simultaneous in-HH and business use. Bedroom is considered to be the safe place as it is the private space in the house and generally out of sight for anyone who comes inside. Visitors are commonly accommodated in the living room which is typically the room one steps immediately into while entering the house (refer to Figure 4.56 in section 4.1.1 for a drawing of a common rural house).

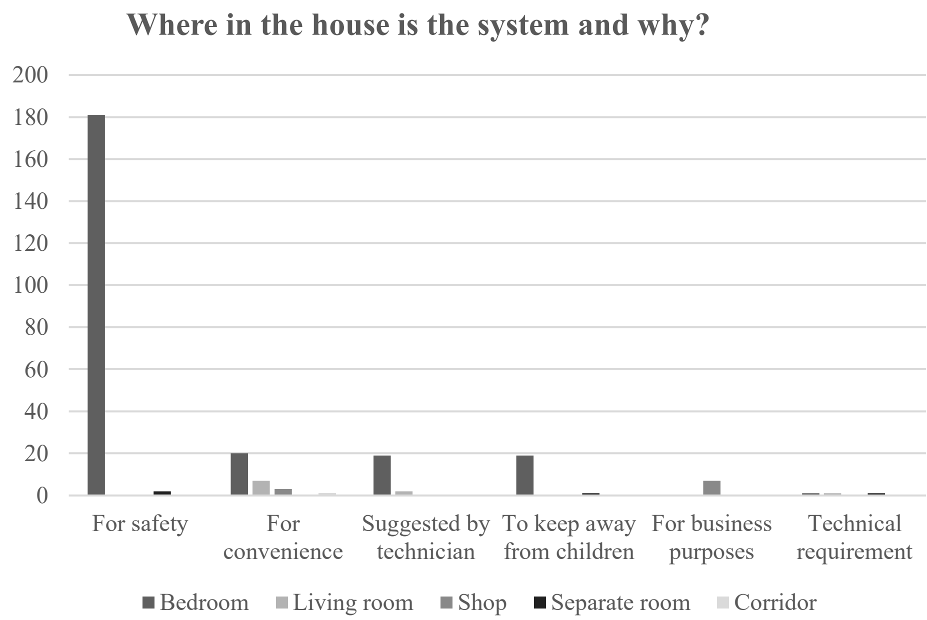


Figure 5.1. Breakdown of system location in respondents' houses and the reasons for choosing that location (n=265).

There were individual instances of HHs where the system would also be covered, either with the original packaging (as shown in the image below) or with a piece of fabric/other type of cover for protection and to avoid mechanical damage. The careful

[32] What is meant here by the system is the Control Unit (CU) which is the part containing the battery, USB ports and on and off switches (though not the light switches).

treatment of the system CU and the appliances was noticeable and often accompanied by a perceptible sense of pride and satisfaction. FG1(2) participant explained why he kept his system in the bedroom and kept it covered:

> "The system is good and is kept in our sleeping room. This is because I want to take care of it and prevent any damage that might arise caused by children." (Mae participant, FG1(2), Bigogwe)

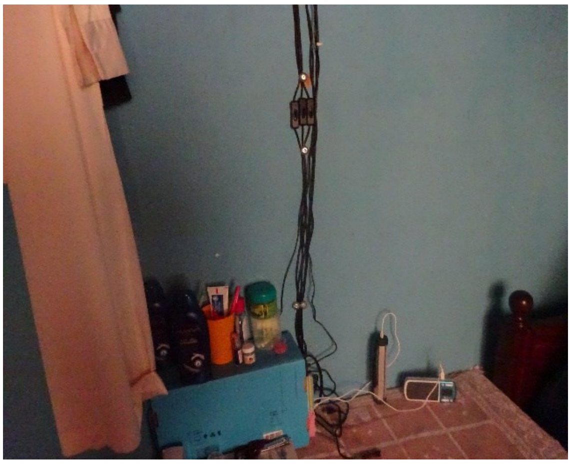


Figure 5.2. Examples of CUs being kept in the original packaging (the protective film or the packaging box) for protection. Image to the right taken in a bedroom. Photo credits: M.Uwase & I.Bisaga.

Figure 5.3. An example of the SSHS at a place of business. PPW12 participant has his system installed at the bar which he runs. Photo credit: I.Bisaga. To the right: An image demonstrating where the SSHS is placed in a house most frequently (i.e. bedroom, followed by the living room and a separate room/storage).

When asked about the design, or in simpler terms the physical look and shape of the system, nearly 60% of respondents said they liked it. However, when asked about how well the SSHS integrates in their houses, i.e. how well its design and different components fit in given the layout of the house, only 15% of respondents said it integrated well (Figure 5.4).

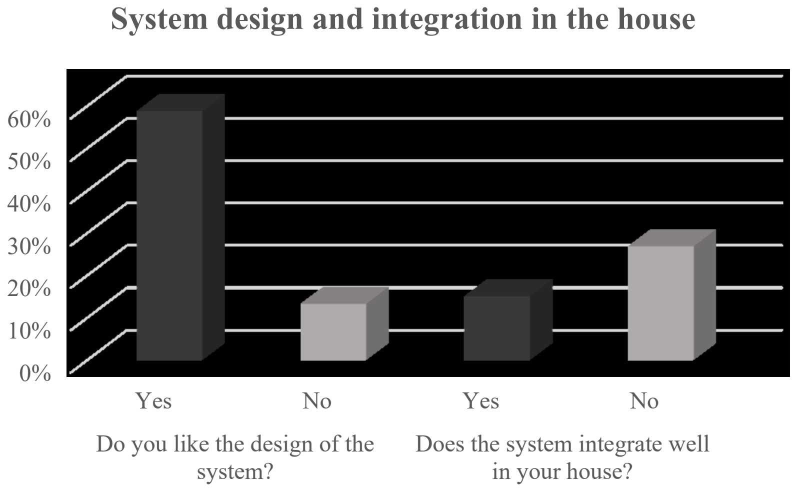


Figure 5.4. Multiple-response question on system design and integration in the respondents' houses (n=265, total responses=303).

One of the key challenges with the integration was the fact that switches for the lights (regardless of how many were owned in a given HH) were all centralised, meaning that there was one switch for all lights. That made switching individual lights on and off in different rooms impossible. As put by FG1(5) participant:

> "The integration in my house is not really good because of the way the switches are all placed near the battery [the CU] is bad." (Female participant, FG1(5), Gakoro)

Another FG1(5) participant said:

> "I want that they [the provider] increase the length of the cables so that they reach in every room even outside in the kitchen. I also wish that we can switch on lamps in the places they are located in rather than being switched on in single place near the battery." (Male participant, FG1(5), Gakoro)

However, that problem had since been addressed and the design has changed to enable switching off all lights separately (i.e. each light comes with a separate switch). That challenge was present among the customers in Group 1 who had got the older version of the SSHS than those in the other two Groups. Another factor mentioned by all participants was the insufficient number of lights, which was understood as a problem of design and integration because the respondents felt the system, especially in its basic package (2 light bulbs), did not come with enough lights for how many rooms or areas there are in and around the house. Respondents also felt that there were too few USB ports, which was problematic mostly because they limited the number of charging ports and thus the number of phones that could be charged at any one point. Similarly as in the case of light switches, that aspect of system (incl. appliance) design had been addressed and changed into a charging port with multiple USB outlets in the process of product development (see Appendix 1 for an example) and therefore predominantly affected the customers who adopted their SSHS over 12 months before the time of data collection (Group1, with a few in Group 2). Too few USB ports (on the CU) were also mentioned as a design flaw because fewer appliances, overall, can be used with the system. Customers who felt they should be able to use other USB compatible appliances with their SSHS were those who deemed this to be one of the pitfalls. Battery which was seen as not strong enough (draining too fast) was the last weakness in system design pointed out by respondents who felt there were issues with system design and integration. This concern shared by 32% of those unhappy with system design, was put forward by one of the survey (S3) respondents here:

> "I can light our house, but the battery is not very strong. I can't light the outside of the house during the night." (Female respondent, S3, Gakenke)

In three out of five FG1s there was a mentioning of weak batteries among participants, however, in most cases it referred to overcast days and the rainy season.

FG1(1), FG1(3) and FG1(4) participants who owned radios voiced their opinions on them being too small and the quality of sound being too poor, with no alternative to plug in other radios. Radios as SSHS appliances have indeed proven challenging and have changed several times over the period of the last 2-3 years of operation. The poor quality of sound was a result of poor reception, which concerned the antenna in the radio, picked up by customers using radios as a design challenge (internal vs external antenna in different radio designs). A similar problem was observed with those owning TVs who often were not be able to watch TV channels due to poor reception. However, this was a problem observed in remote areas with poor coverage and despite improved designs proved to be difficult to address. It was perceived as a SSHS design (and service) issue, however, and was raised by 7 out of 9 FG1(4) participants, who considered it to be a major problem as a TV was one of the main reasons why they purchased the system.

Despite the noted downsides of the SSHS design and integration, over 80% of respondents also expressed their satisfaction with the lights and having a bright environment in their house. The value attached to the ability to light up a house was indisputable and will be further elaborated on in the following section which looks at the most useful appliances as declared by study participants.

It has to be noted that this question along with the questions on reasons of purchasing a SHS and motivations for choosing a BBOXX SSHS examined in section 4.3.2, highlight the importance of semantics and making sure notions explored in any given question have to be clearly explained to the respondent who might understand certain concepts differently or be unfamiliar with them, thus providing responses which do not directly answer the question despite being related to it. Translation and the meaning lost in the process of translating questions or descriptions can also impact on the reception and understanding of the question and are therefore critical to carefully consider in the course of research design. This subject will be further addressed in the brief discussion of study limitations (section 7.4).

5.1.1.2 How?

Study participants found the use of the system easy and straightforward. 97% of survey respondents said they believed they were using the system correctly. Only 1% said they did not and 2% did not know whether or not they were using it in the right way. Among all FG1(1-5) participants, everyone except for one female participant in FG1(1) (who was not the owner of the system) and toddlers as mentioned by participants who had toddlers at home knew how to use the system. Each customer, at the time of system installation by the company's technician, is trained on how to use the system: the best practices for how to use it and how long for in order to achieve the best level of efficiency (for each appliance the customer has purchased), what each component is, what the indicators mean (e.g. battery level), how to plug and unplug the panel from the CU, and basic information on how the energy conversion works, i.e. solar energy captured through the panel (which is also installed by the technician) is transformed into electricity, is also provided. The technicians perform the installation according to a standard guide which they are all required to use and obey at each installation. Yet how the training is conducted and what exactly is communicated at each installation might vary among technicians, depending, for example, on how much time they have. If there are many installations scheduled on a given day, they might be in more rush than on days when there are fewer, thus dedicating more or less time to each customer they perform the installation at. Furthermore, who receives training is determined by who is present at home at the time of installation and therefore rarely do all HH members get the training as installations happen throughout the day and it is not always possible to ensure all HH members are around. Those who do receive usage training usually pass it on to others, however, it does not always follow the exact guidelines. The proportion of female and male respondents who received training at the time of installation is nearly exactly the same, similarly as the proportion of female and male spouses (Figure 5.5). Children, if present at the time, also participate in the training by observing and listening in. The novelty aspect of the system attracts their attention and those who are not actively prohibited by their parents to use the SSHS, know how to switch it on and off, and how to use the appliances.

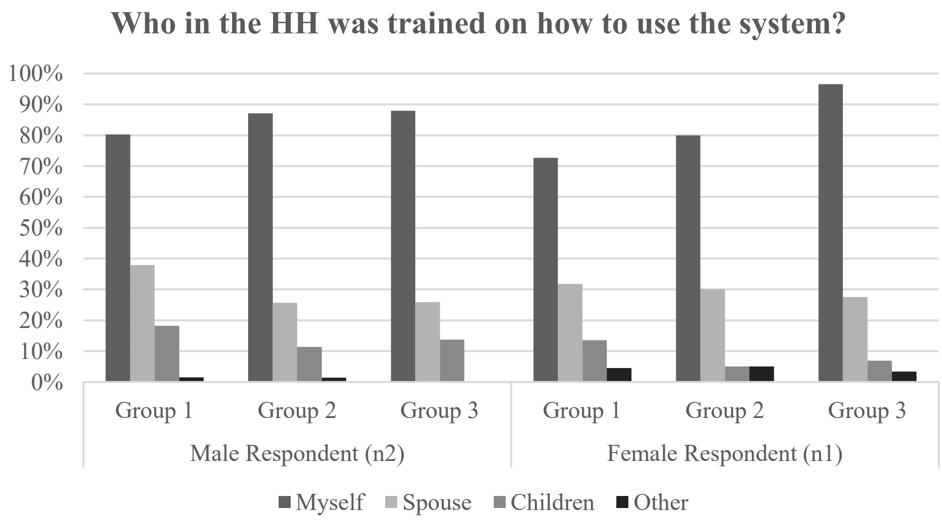


Figure 5.5. HH members trained on SSHS use at the time of installation split by respondents' gender (n1=71, total responses=89, n2=198, total responses=253).

When considering the length of use of the system, both male and female respondents received training more often in Group 3 than Group 1 and 2 with an increasing trend from Group 1 to Group 3, while the trend for spouses' training was the reverse: more spouses were trained in Group 1 than in the other two Groups. This, however, might be the result of recall bias where participants who had purchased their system and had it installed over 1 year ago at the time of the survey could remember the installation and the training, and who was present, less well than those who had adopted the system less than 6 months ago at that time, making it more recent and therefore more likely to remember it correctly.

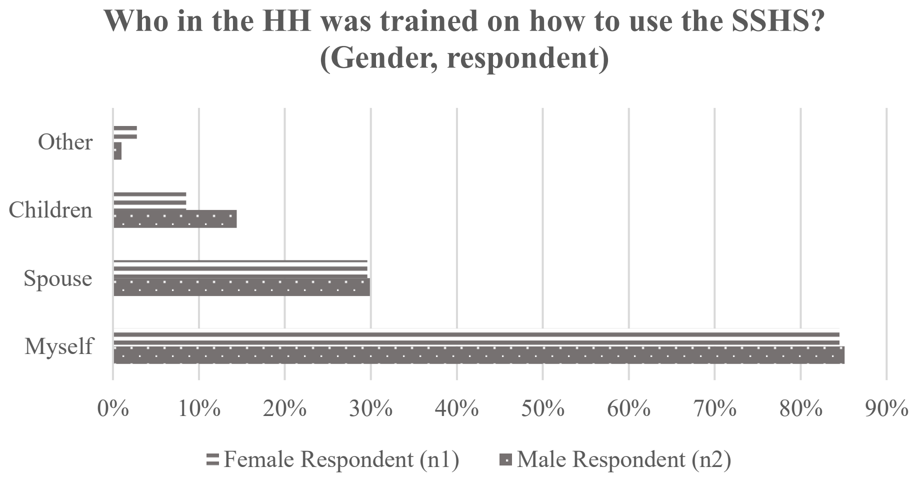


Figure 5.6. HH members trained on SSHS use at the time of installation split by respondents' gender (n1=71, n2=198) and different Groups (n1: Group 1=22, Group 2=20, Group 3=29; n2: Group 1=66, Group 2=70, Group 3=58).

Even though training was received by a high number of survey respondents, 72% of all participants said they had not been instructed on what the recommendation was on how long they should use each appliance for to achieve best system performance, while 23% said they had and 5% did not know or remember whether or not they had. Instructions on the recommended hours of usage of each appliance were a part of the standard installation procedure in the case of all customers, regardless of when they had purchased their system and what system they owned (in terms of system package, whether BB Lights, BB Super Lights, BB TV or Ikaze or Aguka) and the proportion of those who said they had not been instructed on best usage practices was similar across all three Groups (between 69% and 75%). Among those who were instructed, when asked about what the recommendation was, the responses were diverse and showed a rather low level of consistency. The most common answer was to not exceed

4 hours of total usage of the system per day. For the full range of responses see Table 5.1 below. The variety of answers among FG1(1-5) was equally high which supports the claim that customer education on system use was not fully congruent with the standard guide and across the HHs and the technicians performing installations.

SSHS Usage Instructions	Frequency	%
Don't exceed 2 hrs (total per day)	1	1.6
Don't exceed 3 hrs (total per day)	4	6.6
Don't exceed 4 hrs (total per day)	33	55
Don't exceed 4 hrs (lights only, in rainy season)	1	1.6
Don't exceed 5 hrs (total per day)	3	5
Don't exceed 6 hrs (total per day)	2	3.3
Don't exceed 8 hrs (total per day)	1	1.6
Don't exceed 12 hrs (total per day)	1	1.6
Don't exceed 2100hrs	3	5
Don't exceed 2200hrs	5	8.2
Don't exceed 0000hrs	1	1.6
1800-2200hrs	2	3.3
Can use all day	1	1.6
Stop using at 20% battery	1	1.6
1 light can be on for the whole night	1	1.6
System can be on for 3 days (non-stop)	1	1.6
TOTAL	**60**	**100**

Table 5.1. Range of system use instructions received at the time of installation by survey respondents who claimed they had received recommended use training (n=60).

Although there was an overwhelming positive feeling about their know-how of how to use the system, interest in receiving more training on the correct use of the system was expressed among FG1(1), FG1(2) and FG1(5) participants. They all felt that it was easy to use the system, however, they were keen to better understand when to switch off the system, what practices of switching the appliances on and off are best and how to check the battery status, i.e. whether or not it is working properly and how much time of being able to use the system appliances is left (rather than just being told an X% of the battery capacity is left). Those participants who said they would find it useful also stated that being able to fix small issues themselves would save them from having to call the Customer Service Call Centre every time something malfunctions or goes wrong. Participants of FG1(3) and FG1(4) had a different attitude with a majority content with the level of knowledge on system use they possessed and with the customer service support offered to them they did not feel knowing more was necessary.

Whether or not a customer received recommended use training at the time their system was installed in the house did not determine how often they would run out of energy, or whether they would not run out of energy at all. As shown in Table 5.2 below, the highest percent of customers who said they do not run out of energy was among those in Group 1 who claimed to not have received recommended use training, while Group 3 had the highest percent of customers who do not run out energy among those who did receive recommended use training. On average, respondents in Group 1 reported running out of energy the least, with no instances of users who would often run out of energy.

Group	Received SSHS training?	Run out of SSHS energy?	Frequency	%
Group 3	No	No	**33**	**55.0**
		Yes, sometimes	20	33.3
		Yes, often	7	11.7
		Total	60	100.
	Yes	No	**15**	**60.0**
		Yes, sometimes	6	24.0
		Yes, often	4	16.0
		Total	25	100.
	Don't know/remember	No	**1**	50.0
		Yes, sometimes	1	50.0
		Total	2	100.
Group 2	No	No	**28**	**43.8**
		Yes, sometimes	30	46.9
		Yes, often	6	9.4
		Total	64	100.
	Yes	No	**9**	**45.0**
		Yes, sometimes	10	50.0
		Yes, often	1	5.0
		Total	20	100.
	Don't know/remember	No	**4**	**66.7**
		Yes, sometimes	2	33.3
		Total	6	100.
Group 1	No	No	**44**	**66.7**
		Yes, sometimes	22	33.3
		Total	66	100.
	Yes	No	**7**	**46.7**
		Yes, sometimes	8	53.3
		Total	15	100.
	Don't know/remember	No	**4**	**57.1**
		Yes, sometimes	3	42.9
		Total	7	100.

Table 5.2. Frequency of respondents running out of SSHS energy according to whether or not they received SSHS use training and the Group (length of system use) (n=265).

Among the 120 (45.3%) respondents who said they did run out of energy, either sometimes or often, 24% would usually experience it in the evening and 17% in the rainy season. Only 3% would run out during the day. Rainy season in Rwanda, and in particular in the highlands in the North-Western part, is characterised by daily rainfall and predominantly overcast skies. Even though the battery continues to charge, it might take longer to reach full charge than on sunny days. Combined with sustained system use throughout the day, the likelihood of running out of power in the evening hours increases. With heavy use of the system throughout the day, even in dry season when irradiation levels are higher (clear skies), cumulative power stored in the battery might not be sufficient to support appliance use throughout the evening and into the night time. Heavy use of all appliances in the evening might yield a similar result. In four out of five FG1s participants also expressed concern about being able to use the system less in rainy than dry season. FG1(2) participant summed it up saying: "We only lack electricity when the weather is too bad, when there is no sun. It also happens to me when I delay my payment". If a customer delays a payment, the SSHS is automatically switched off. It gets switched back on when the payment is made. Two participants of FG1(5) also noticed the wear and tear of the battery, saying: "For the past months my battery drains faster, and I am frightened about what will happen when I finish to pay off [the system], and all the privileges will be taken away, and the battery may not last even 2 hours for lighting. They [BBOXX] should find a way to solve this", while another one said: "It [the battery] runs out around 1900-2100 hours depending on the weather. But before it used to last longer". An estimated lifetime of a lead-acid battery is approximately 5 years, depending on the use patterns. The capacity of the battery decreases over its lifetime and for those customers, given that they had both been using their systems for nearly two years at the time, this change became noticeable. The concern of losing service support post repayment period (3 years) was expressed by other participants in the survey and FGs, as well as during PPWs and it will be discussed in section 5.1.4 which looks at the use of services among study participants.

5.1.1.3 Who? When? Why?

The SSHS is used[33] by different HH members as demonstrated below in Figure 5.7. Respondents, their spouses and children all make use of the system, with other family members occasionally using it as well.

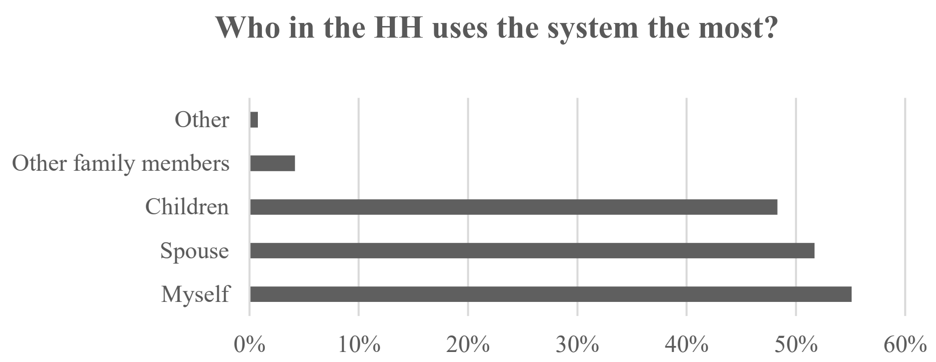


Figure 5.7. System use in the HH as reported by the survey respondents (n=265, total responses=424).

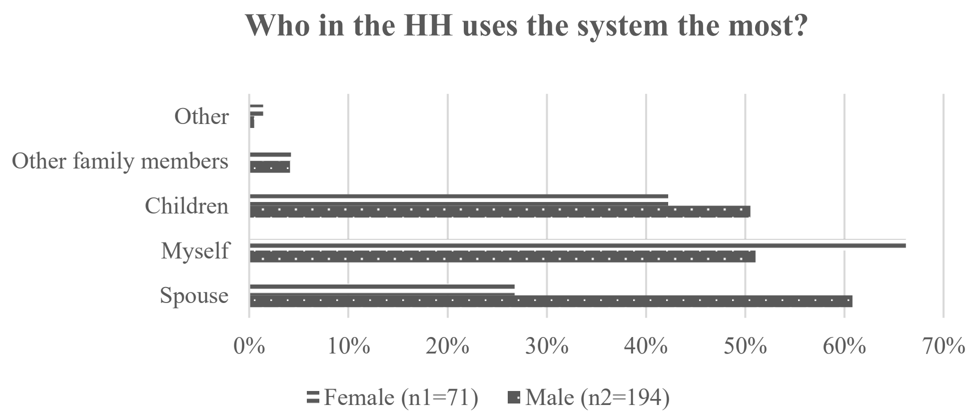


Figure 5.8. System use in the HH as reported by the survey respondents (split by gender) (n1=71, total responses=100; n2=194, total responses=324).

However, splitting the above according to the gender of the respondent shows that women are the ones who use the system the most (Figure 5.8).

60.8% of men indicated that it was their spouses who were using the SSHS the most while only 26.8% of women did. Women also saw themselves as those using the system more ('myself' made up 47% of their responses vs 'spouse' at 19%). FG1(1-4) participants, both male and female, nearly unanimously agreed that it was the wife, or the woman, and the children in the HHs who make the most use of the system. The

[33] What is meant by system use is the use of services offered by it and its appliances, i.e. lighting, phone charging, listening to a radio (where applicable), watching TV (where applicable), etc. collectively referred to as 'system use'.

main reasons as listed out by the participants were that: she is always home, together with children they spend more time at home than the man does, the wife uses the system to do chores (cooking, washing etc.), and children use it to revise their studies and play in the evening. However, despite women and children being the ones who use the SSHS the most, by the nature of their daily routines which involve more time spent at home than those of men, and otherwise all HH members being free to use the system when needed, when asked about the responsibility for system maintenance and for making the (monthly) payments, both fell mostly on the husband or the male head of the HH. In all FG1(1-5) all male participants named themselves as those responsible for maintenance, i.e. making sure the system works properly and calling the CSCC in case anything goes wrong or the system stops working due to fault rather than late payment, whereas all female participants, apart from two women in FG1(5) who were the HH heads, said it was their husbands who assumed that responsibility.

Survey results returned a somewhat different picture, with more women reporting being responsible for system maintenance themselves, as shown in Figure 5.9 below. The graph demonstrates the responses of survey respondents and whilst not all of them were the registered owners of the system, in both cases of men and women irrespective of ownership, they claimed system maintenance as their responsibility (82.4% among male owners and 83.3% among male non-owners; 78.3% among female owners and 76.5% among female non-owners).

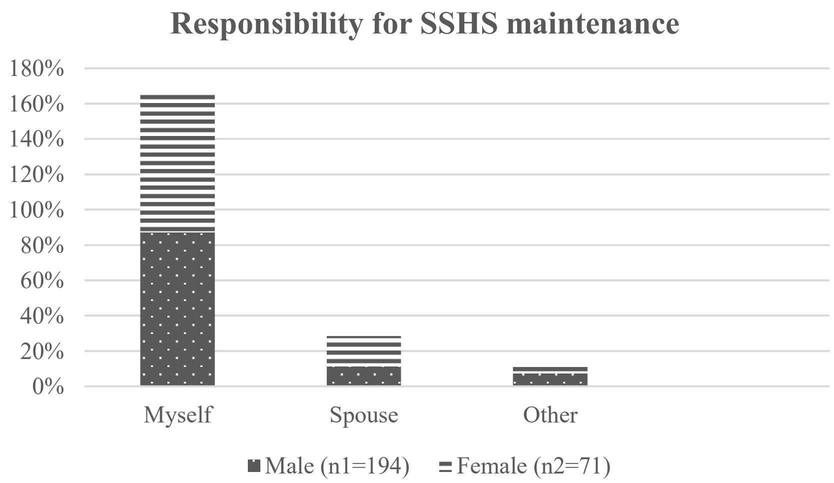


Figure 5.9. Survey responses concerning responsibility for system maintenance split by gender of respondents (n1=194, total responses=205; n2=71, total responses=72).

Women were, however, more likely to indicate their spouses as the ones holding the responsibility than men doing the same regarding their spouses. Others responsible for maintenance also included older children in the family either still residing or no longer residing in the HH.

This disparity between FGs and survey could be the result of the distinct dynamics of providing responses while in a group setting (in the case of FGs) versus in a one-on-one telephone or in-person interview. As none of the FGs consisted exclusively of female participants, the presence of men might have influenced the responses of female participants who echoed the responses of the men, who all, without exception, declared themselves to oversee system maintenance. As women spend more time at home and therefore tend to use the system with its appliances more than men, on average, they can experience issues with the SSHS at times when the man is away and deal with them despite not always being the registered owners. Making the monthly payments is predominantly also the responsibility of the husband or the man in the HH, where a man is the household head. That was supported by all FG1(1-5) participants other than FG1(5) where two female participants where the HH heads and responsible for making the payments which also validates the observation that in HHs with a female head, it is the woman who is in charge of managing the payments and matters related to the SSHS. In instances where another family member, who might no longer be resident in the HH, is responsible for the system (e.g. when a system is purchased for an elderly parent/elderly parents who live in a village and the son/daughter live elsewhere), they will be the ones ensuring monthly payments are made and the system is functioning well.

The dynamics of energy use in the HH are complex, with power and agency playing a role in who takes ownership of the system and assumes the responsibility of its maintenance or, in other words, sure ensuring maintenance support is sought in times when it is needed. Yet despite the complex interplay of roles and responsibilities, all HH members make use of the system and experience the benefits of lighting, phone charging, and other services available to them through the appliances included in their specific system package.

5.1.2 Energy use post-adoption

This section looks more closely at the energy use in the HH. It examines the actual energy usage as monitored through the SMART Solar platform, taking a snapshot of power consumption data of the survey participants in the time between July and September 2016, and the self-reported energy use as declared by survey respondents. It shows what appliances adopters of SSHSs commonly use at what times on an average day. Usage and consumption are compared among the three Groups and questions are raised about whether power consumption increases with time, i.e. whether the longer the customer is using the system for, the more likely she or he is to consume more power.

The composition of energy fuels in the HH changes after adopting a SSHS, most considerably in terms of energy sources used for lighting. The observed reduction in use among lighting sources is the following:

- Kerosene – 98.2% reduction
- Candles – 90.2% reduction
- Batteries (for torches) – 94.5% reduction
- Grid (for lighting) – 50% reduction

Only one respondent declared using phone torches for lighting before purchasing a SSHS and continued to use it after adoption. The change patterns in the use of energy fuels in the HH are shown below (Figure 5.10).

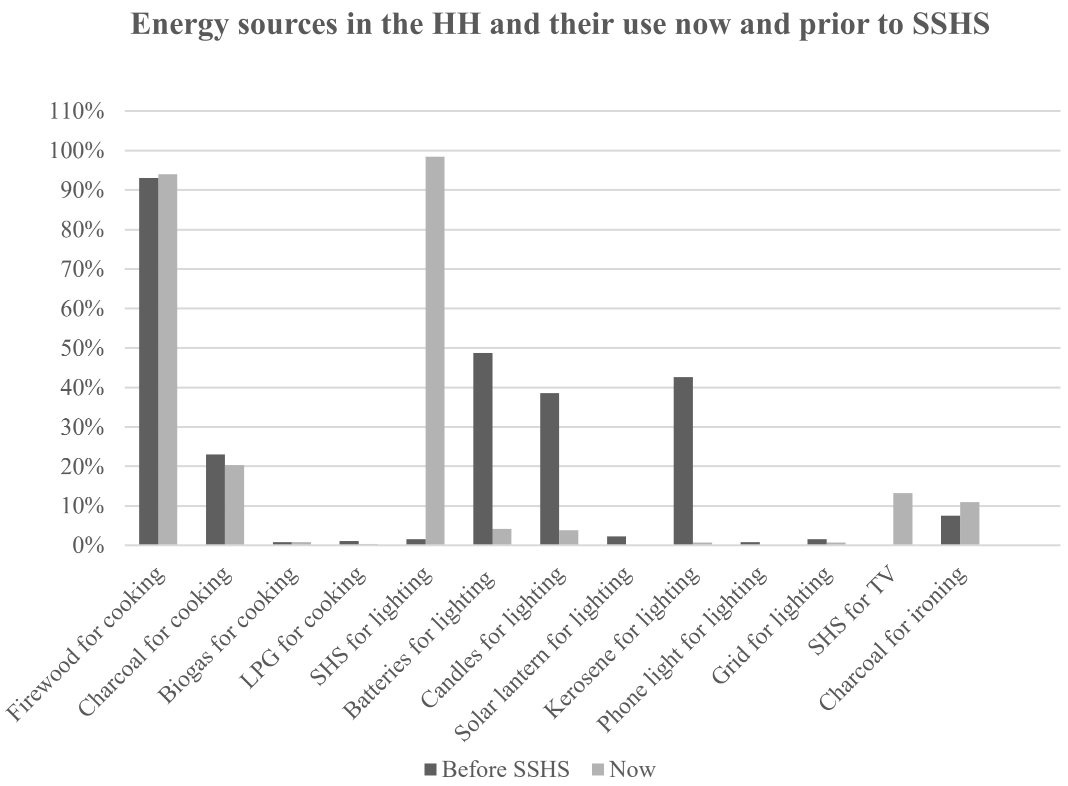


Figure 5.10. Energy sources in use before SSHS and now. SHS refers both to another SHS owned before and the SSHS owned currently (n=265, total responses before=695, total responses now=659).

Despite the significant decrease in use of polluting fuels such as kerosene and candles to light up the houses, there has been little to no observed decrease in the dirty and inefficient cooking fuels, including firewood (0.8% increase) and charcoal (11.5% decrease). Although the use of charcoal has gone down, its use for ironing has increased by 45% (among female respondents). The reason for that increase is unclear, however, could be the result of a) an iron[34] being purchased after the adoption of a SSHS, b) the ability to use the previously purchased iron as a result of being able to pay for charcoal, or c) another circumstance associated with a new or pre-existing need to use an iron in the HH. Those using batteries for radios continued doing so as they retained their radios, having no radio included in their system package.

When talking about changes in the HH regarding energy fuels, both FGs and PPWs participants stressed the shift towards a considerable decrease in the purchases of

[34] Charcoal-fuelled irons remain very common in rural areas where no alternatives are available if there is no connection to the grid which can power an electric iron. Irons, as will be shown in section 5.3.2, are one of the most desirable appliances among HHs, especially among women.

previously frequently utilised kerosene, candles or batteries. Two female participants of PPWs reported it saying:

> "I used to buy candles and kerosene every day, but it has now reduced."
> (Female participant, PPW4, Muhanga)

> "Before we used to spend a lot on batteries as compared to now."
> (Female participant, PPW3, Muhanga)

Another female participant of PPW19 spoke about the need to purchase many batteries very frequently as the house her family live in is big and when the grid power goes off they would always use torches. With a family of 8 the need for batteries was very high (frequently 10 or more batteries a week, coming up to approx. RWF9000/month). Despite their good economic status (falling under LLP on the PPI scale), the expenditure on batteries was becoming burdensome.

The use of alternative sources does not decrease completely, however, as at times when the system goes off (whether due to late payment or a technical fault), the need arises to resort to the available sources, often going back to those that had been used prior to owning a SSHS. In instances where the power goes off due to late payment, the challenge that is created is that the resources which would otherwise be put towards that payment are now channelled into purchasing lighting fuels for the immediate use, thus making it harder to then catch up on gathering the whole sum for the SSHS payment and settling it in order to be able to use the system again. Situations like this create a vicious circle of energy insecurity and can be one of the causes of customers defaulting on their payments and having their systems repossessed, effectively returning to the polluting, inefficient and relatively expensive (given the volume that is required) lighting sources, and the use of indispensable services such as phone charging externally at charging stations or elsewhere. Another reason why the use of candles and batteries, and much less frequently kerosene, which is eliminated by nearly 100%, is that if a customer does not have a sufficient number of lights included in his or her system package, the need to use other lighting fuels remains so that more rooms and areas around the HH can be lit up. As stated by the survey (S2) respondent:

"I like how it helps lighting our house, but the lights are few that we always buy extra energy." (Male respondent, S2, Gasiza)

Even though theft of solar panels and SSHS appliances has not been reported by study participants as common, there have been recorded instances of outdoor lights being stolen (among all system components, they are the easiest target for thieves). The wife and husband who both participated in PPW2 experienced theft of one of their lights, leaving them with one light only, which is not always enough. Being unable to afford another lightbulb, they were left with very few choices but seeing how impactful the system has been on their daily lives, they decided to continue using it with one light only, despite having to pay for the original package with two lights. As their house has 3 other rooms, they still occasionally use a torch or a candle to light up areas where the system light does not reach.

Lights are predominantly used in the evening hours, in rooms which are being occupied, as shown in Figure 5.11 below for customers who use their systems at home (rather than at a place of business).

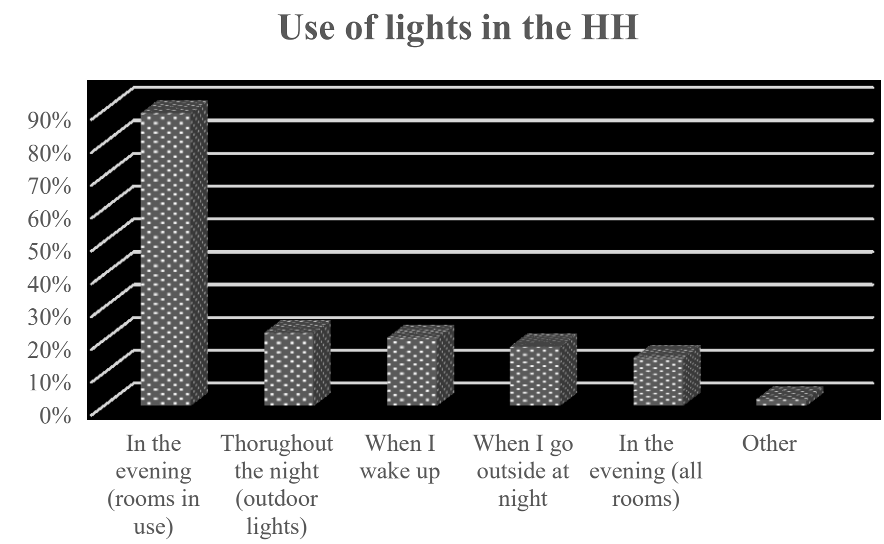


Figure 5.11. Light use with an indication for time and area of the HH (n=263, in-HH system use only, no business users).

Those using their systems for business purposes switch on the lights in the evening in the occupied rooms/areas (at a bar and at a shop).

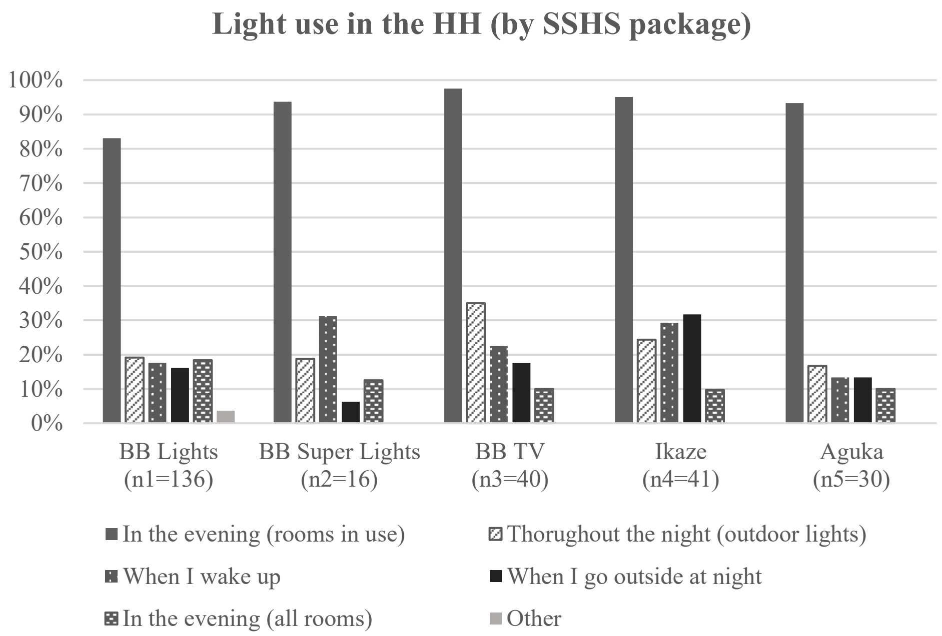


Figure 5.12. Light use in the HH split by system package (total n=263; n1=136, total responses=215; n2=16, total responses=26; n3=40, total responses=73; n4=41, total responses=78; n5=30, total responses=44).

No considerable difference between various system packages and the use of lights is present in the study among survey respondents (Figure 5.12), with the most common use being lighting of occupied rooms in the evening followed by having the outdoor light on throughout the night and switching on the lights in the morning after waking up. Outdoor lights are left on at night for safety reasons, whereas morning hours' use of lights helps HH members get ready for work and school. With the sun rising at approximately 6am every day, those who start the day early experience a relatively dark indoor environment where looking for objects (e.g. clothes, tools, etc.) can be challenging and made easier and faster with the lights on. Among respondents who use the Ikaze system package (predominantly lights and phone charging only), there is a higher use of lights while going out at night, however, female and male respondents use their systems similarly. Even though both men and women value the use of lights while stepping out of the house at night, the importance of having the ability to use lights in the evening or at night has been stressed by women during FG discussions and PPWs. One of the female PPW participants expressed her experience of fearing going out at night before getting the system:

> "I used to use kerosene and I could not go to the toilet or even outside in the evening, I was scared, but now I have put lights outside and inside the house, I am no longer afraid to go out." (Female participant, PPW20, Nyanza)

Lights have been consistently named as the most useful appliance owned by a great majority of study participants. There were followed by the phone charger, as shown in Figure 5.13 below.

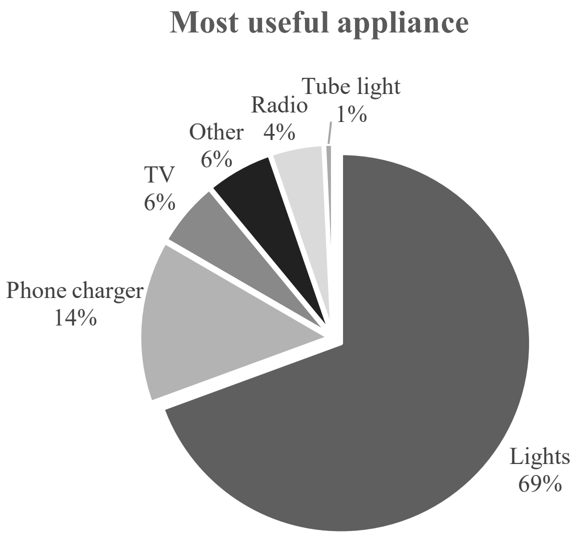


Figure 5.13. Most useful appliance among survey participants (n=265).

6% of all survey respondents indicated a TV to be the most useful appliance, which made up 37.5% of those who owned a TV in their system package. 'Other' consisted of responses including 'lights and phone charger' and 'all appliances'. Collectively, over 75% of survey participants pinpointed lights as the most useful appliance(s). Reliable, bright lighting has proven to have a transformative impact on the HHs which will be discussed in the following sections (with the focus on impact in section 5.4).

5.1.3 Energy consumption and social practices

This section consists of an abridged version of the researcher's article published in the Energy Research & Social Science Special Issue on Solar PV in Africa (May 2018) (for a full article see Appendix 18):

Bisaga, I. and Parikh, P. (2018). To climb or not to climb? Investigating energy use behaviour among Sola Home System adopters through energy ladder and social practice lens. *Energy Research & Social Science*, 44(2018), 293-303.

We focus on energy consumption and practices relying on access to electricity services (e.g. using light, charging mobile phones) which are supported by the SHS systems. Table 5.3 and Table 5.4 below demonstrate what kinds of system packages (under System Name), as available from the provider, and appliances that come with them are present in our sample. Lights are the one appliance owned by everyone with other appliances distributed in different numbers across system packages and the three Groups.

Group Name	System	Cost (per month)	Frequency	Frequency (SMART Solar)	Appliances	Number (cumulative)	Number (cumulative SMART Solar)
Group 1	BB Lights	RWF6000	64	51	LED bulbs	197	151
>1year	BB Super Lights	RWF11500	7	3	Torch light	30	16
	BB TV	RWF14500	16	10	Phone charger	84	64
	Total		**87**	**64**	Radio	72	53
					TV	14	10
Group 2	BB Lights	RWF6000	61	55	LED bulbs	211	195
6-12months	BB Super Lights	RWF11500	6	5	Torch light	33	32
	BB TV	RWF14500	22	22	Phone charger	82	76
	Aguka	RWF5850	1	1	Radio	68	63
	Total		**90**	**83**	TV	23	23
Group 3	BB Lights	RWF6000	12	11	LED bulbs	236	190
<6months	BB Super Lights	RWF11500	2	2	Torch light	6	6
	BB TV	RWF14500	2	2	Phone charger	82	66
	Ikaze	RWF3900	42	32	Radio	25	20

	Aguka	RWF5850	29	23	TV	3	3
	Total		**87**	**70**			
TOTAL			**264**[35]	**217**			

Table 5.3. Numbers of various system packages among study participants in each Group, including the default price for each system package (in Rwandan Francs - RWF), which can vary depending if extra appliances have been added to the original package.

System Name	LED Bulbs (1.2W)	Torch Light (4.2W)	Phone Charger (5W)	Radio (5W)	TV (7-9W)
BB Lights	2	0	1	0*	0
BB Super Lights	3	2	1	1	0
BB TV	3	1	1	1	1
Ikaze	2*	0*	1	0*	0
Aguka	4*	0*	1	0*	0*

*These appliances could be added to the initial set packages at the time of purchase or after a period of time. Additional light bulbs could also be added.

Table 5.4. System packages and appliances included in each of them, and their capacity (in Watts (W)). There are variations among customers, among Ikaze and Aguka owners as there was more flexibility in choosing appliances at the time of purchase and as upgrades. See Appendix 11 for details of the change in available packages as introduced by the provider.

In the following sections, we will first look at a snapshot of how energy is used in the household by examining the appliances and the time(s) of their use throughout the day as self-reported by survey respondents and the data collected from the systems through remote monitoring. We also compare the usage among Group 1, 2 and 3 to check for any differences in usage patterns and levels depending on how long the systems have been in use for, which we assume to be one of the indicators of whether or not users

[35] In the sample of 265 respondents, one respondent failed to complete the self-reported energy usage matrix hence the total sample here is 264.

climb the solar energy ladder by using more energy the longer they use their systems for. We then explore the question of productive uses of SHSs, which is another indicator pointing to whether or not access to electricity services boosts household economics, as is often expected through the provision of electricity access and has been tested for adopters of SHSs before (e.g. Rahman & Ahmad, 2013). Furthermore, we examine adoption rates of new appliances to challenge the solar energy ladder perspective, while at the same time corroborate the theory that practice change occurs as a result of getting access to additional appliances and thus new energy services. The latter part of it is explored by looking at examples of different SHS appliances to discuss how their use influences practices, causing their emergence, disappearance and/or change.

5.1.3.1 To climb or not to climb the ladder?

Our working assumption derived from the energy ladder concept is that as households gain access to more appliances and with the passing of time they will start using more energy and therefore require ever higher capacity of the systems in order to satisfy the growing use and needs. We test this assumption by looking at the three Groups of customers who own different system packages offered by the provider, and within them different sets of appliances, subsequently looking at their energy use patterns.

Figure 5.14 below demonstrates the collective number of different appliances owned by customers in all three Groups (based on Table 1) and Figure 5.15 provides a cumulative number of all appliances across the same three Groups:

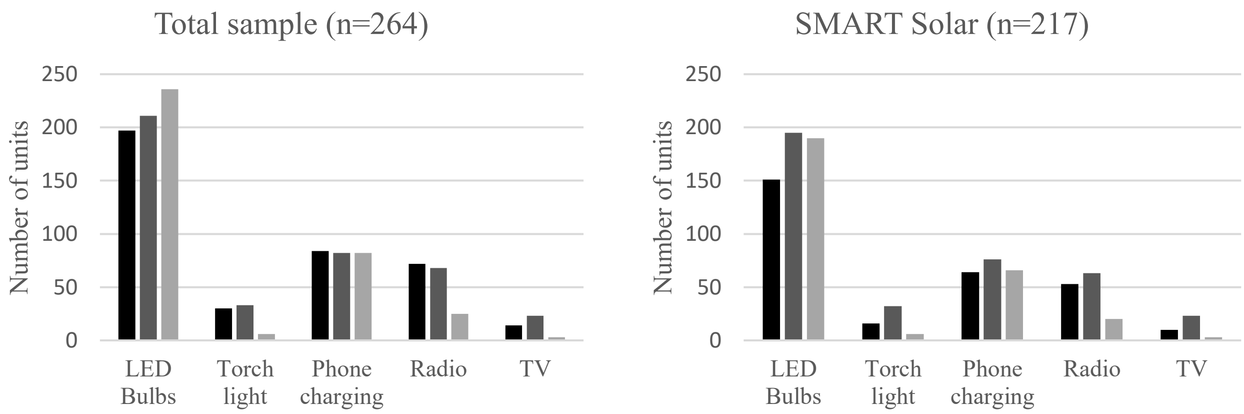


Figure 5.14. The number of different appliances owned in Group 1, 2 and 3 against the average number of individual appliances owned for the entire sample for both the total sample and the SMART Solar data sample.

As shown in the above figures, Group 3 has the lowest overall ownership of appliances, albeit more pronounced in the total sample than in the SMART Solar sample where the cumulative number of appliances in Group 3 is comparable to that in Group 1, with fewest torch lights (portable lights), radios and TVs. The only appliance which Group 3 exceeds the other two groups at is the number of LED bulbs (although that is not the case in the SMART Solar sample where the cumulative number of LED bulbs is just below that of Group 2).

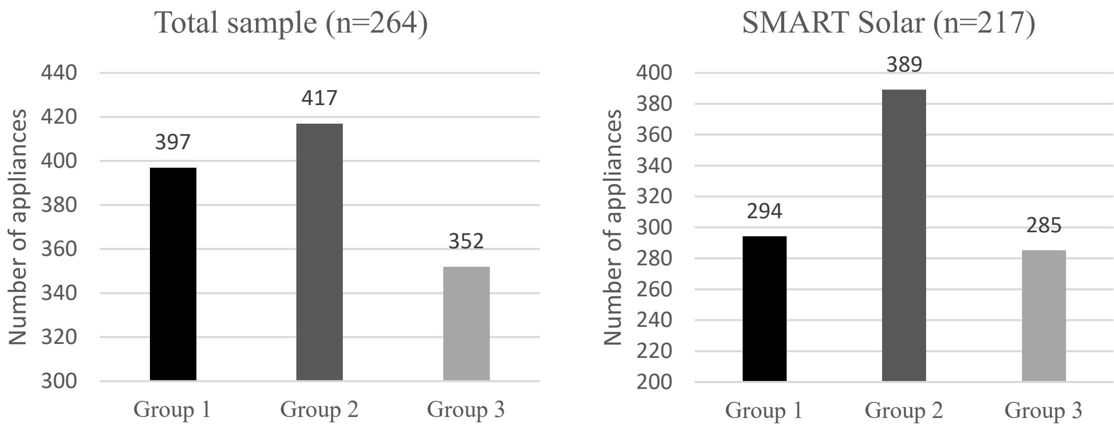


Figure 5.15. Cumulative number of all appliances owned in Group 1, 2 and 3 for the total sample and the SMART Solar data sample.

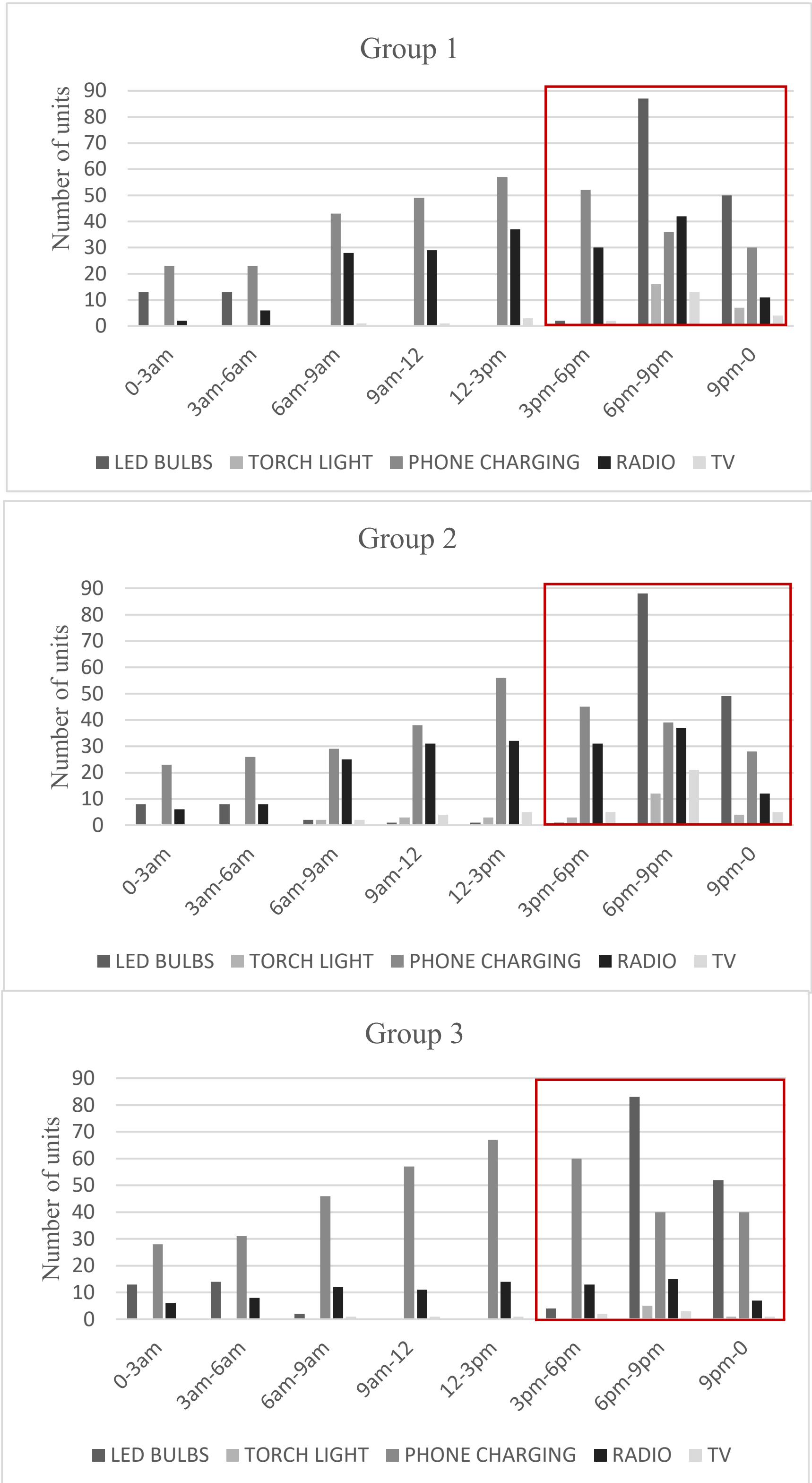


Figure 5.16. Self-reported use of system appliances in Groups 1, 2 & 3. Graphs show the cumulative number of appliances among survey respondents (n=264) used at different times throughout the day and night. Afternoons and evenings are times of highest diversification of use.

The self-reported system uses in Figure 5.16 show how energy consumption is distributed across the day among the three Groups and offers insight into which appliances are used at what times (on an average day). Lights use is the highest in evening times and at night, TVs are used predominantly in the evenings, mobile phone charging throughout the day, evening and night, with other appliances varying throughout the day. Afternoon and evening times show the greatest diversity of appliances in use, clearly demonstrating the more limited range of appliances in Group 3. Households in Group 1 report an overall higher level of usage than those in Groups 2 and 3, however, the use of mobile phone charging is consistently highest in Group 3.

Group 3 own, on average, fewer appliances than those who purchased their SHSs earlier. The six month threshold in this group (i.e. less than six months since purchasing the system) coincides with the change in packages on offer that was introduced by the provider in Rwanda in the first quarter of 2016 and moved away from BB Lights, BB Super Lights and BB TV to Ikaze and Aguka which included fewer appliances by default and required customers to actively add extra appliances (e.g. a radio, more lights or a TV) for a bigger package, automatically increasing the price from the basic to an appropriately higher one (depending on what appliances were added) (see Table 5.3 and Table 5.4). This could have contributed to more hesitation to purchase systems with more appliances as the offer price would no longer hold, i.e. the price the customers would initially see would not be the one they would have to pay. In the case of previous packages, the three different system offerings were sold at set prices for each one, depending on the appliances, and the customer would pay the price of the package they would initially be presented with, e.g. BB TV would always be RWF14500 and BB Lights would always be RWF6000 per month. As rural, off-grid households are very price sensitive, often having irregular, seasonal incomes, the lower the price of a service which can satisfy the basic needs, the higher the likelihood they will decide to purchase it. Any extras, which in the case of SHSs are the additional appliances, are seen as optional and often aspirational rather than critical and can typically be afforded by more wealthy customers.

Despite having fewer appliances (on average), Group 3 have been found to consistently use, on average, more power than the other two Groups (see Figure 5.17 below).

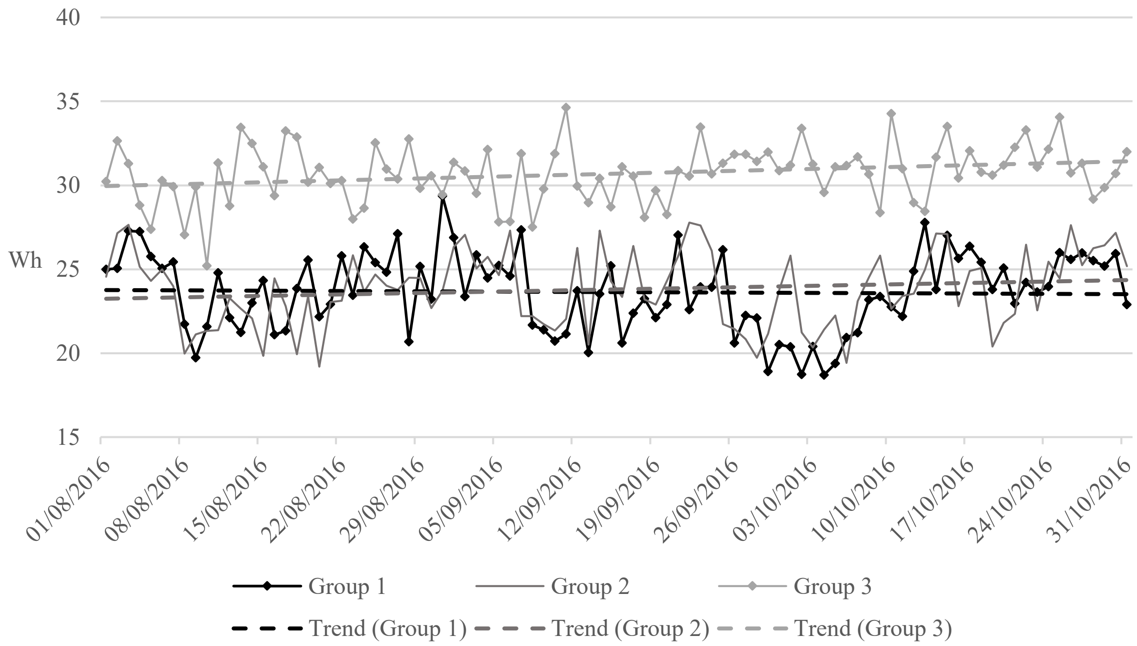


Figure 5.17. Daily energy use (in Wh) per Group across a three-month period between August and October (2016) as shown in SMART Solar data collected via remote monitoring of the systems (n=217).

Considering the lower number of appliances in Group 3, and particularly given the very low number of TV sets which are the most energy-demanding, the obvious assumption according to the energy ladder concept would be that fewer appliances mean less power used. Yet Group 3 maximises the use of available energy with the basic appliances owned, using them more than in the case of the other two Groups. The most notable one is mobile phone charging and, to a lesser extent, lights, which households in Group 3 report to use for income generation, making an average of RWF70 per week, as compared to Group 2 at RWF37 per week and Group 1 at RWF54.5 per week. Group 3 also pay the least for their system per month at an average of RWF5380 (median RWF5850) as compared to an average of RWF7976 (median RWF6000) in Group 2 and an average of RWF7858 (median RWF6000) in Group 1, making it the best value for money use in Group 3. Just like the trend of consuming more power, the trend of using the SHSs for income generation appears to be upward from Group 1 to Group 3, despite the reverse trend of decreasing numbers of appliances owned from Group 1 to Group 3.

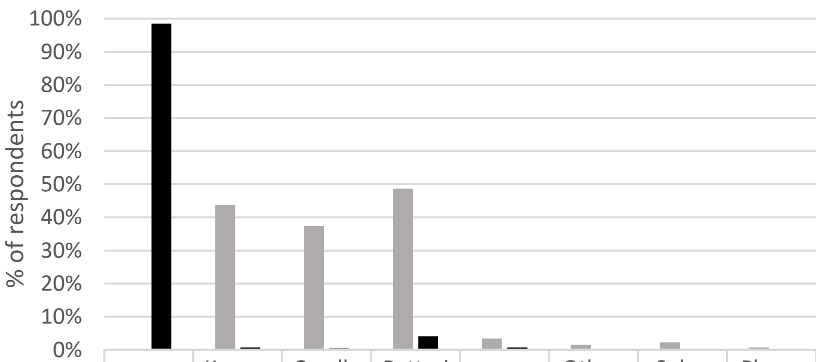
Despite using the most power, when asked if they ever run out of energy from their systems, 56.3% respondents in Group 3 answered no, compared to 62.5% in Group 1 and 45.6% in Group 2. This disproves the assumption that the more power is used the more likely it is to run out of it, and that the more appliances are used with the system the more likely it is to run out of power. This lack of clear relationship between the amount of energy used and a) the number of appliances owned, b) the period of time since system adoption, and c) the need for more power and therefore more system capacity, corroborates the fact that energy is used in a dynamic way, rather than gradually increasing, which the hypothetical solar energy ladder concept would indicate. In terms of household economics, it is not the diversity of appliances that dictate income generation, but rather the maximisation of use and perceived value for money of the available ones. Therefore, more appliances in the household do not automatically increase productive uses and income generation. Overall, productive use applications among SHS users have been observed to be very low, as are incomes generated from those applications, with most adopters using the systems for in-household purposes only.

There is a number of insights which stem from the above. Firstly, energy consumption does not increase in a linear manner depending on the number of appliances owned. Rather, SHS adopters use the systems more dynamically, with some maximising the use of available power with only a few appliances, and others using their systems in a more conservative way while having more available appliances. Those who use the systems for income generation tend to use more power, on average, however, that is independent of the number of appliances owned, as has been seen in the case of Group 3. Secondly, those with more appliances are not automatically more likely to use their systems for income generation, which is proven by the case of Group 1. Thirdly, the overall appliance acquisition is low, and majority of customers do not go beyond the basic ones which include lights, phone chargers and, to a lesser extent, radios. TVs and other appliances are rare as they come at a considerably higher cost, thus remaining predominantly aspirational. From among the n=265, only one customer belonging to Group 3 upgraded the system by adding additional appliances after a year since data collection (i.e. between September 2016 and September 2017). Regardless of how long they had owned the system for, there has been no upward movement on the solar energy ladder in the sense of additional appliance adoption seen among the study participants.

5.1.3.2 SHS and social practices

In the case of SHSs, where energy is collected during the day and stored in a battery with a limited capacity, energy can be used, to an extent, throughout the day and in the evening/at night until the battery drains. The practices associated with energy have to therefore be arranged according to the availability of energy from the system, which in Shove's terms is the *procedures* of energy use (Shove et al, 2012). In this way, the question is not about rearranging practices to best fit the low vs high demand times (as is the need in places with unlimited, reliable electricity where shifting practices are intended for sustainability transitions (e.g. Smale et al., 2017)) but to fit them around times when energy from the system is available, which is also demonstrated in Figure 5.16. They also depend on the available appliances which constitute the *material objects* of energy use. Training and knowledge of how to most efficiently use the system, or the *know-how* of energy use, can help and such training is provided to customers at the time of system installation (which is also the case among other similar providers). However, as practices emerge and change over time, so does the system *know-how*. Customers become more familiar and comfortable utilising the system over time and with use experience, although that adaptation happens quickly, and no sophisticated technical knowledge is required. Across all three Groups, 96.6% said they were able to use the system with ease.

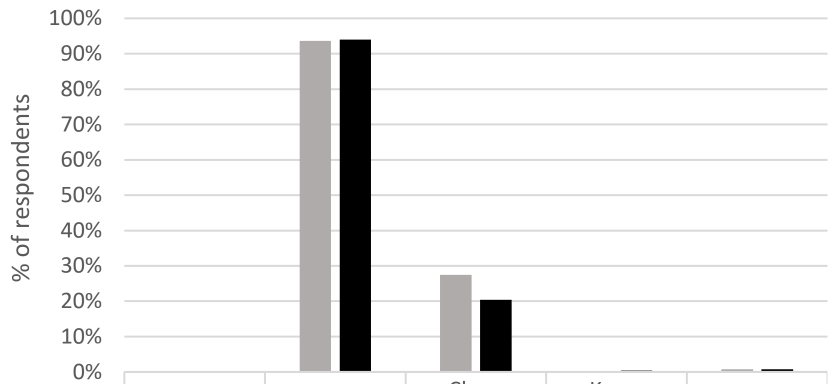
The most common reason for purchasing a SHS among survey respondents was to have light (43.8% of respondents). Light is used in the morning while preparing for work and school and after sunset. In the evening, it enables the performance of various activities around the house, including but not limited to, food preparation and having meals, washing (clothes, dishes, oneself), studying, reading, socialising (with family, friends or neighbours), nursing babies, ensuring security (whether indoors or outdoors), doing work or preparing for work for the following day, playing around the house and other forms of entertainment. Activities which used to be performed in the morning or during the day, while light was available, e.g. washing dishes, have now shifted to the evening. An overall re-scheduling of daily routines and chores has been observed, mostly due to the availability of a reliable lighting source in the evening, which has implications for the *schedules*, as depicted by SPT. In addition to the temporal shift of some practices, there has also been a shift in space, for example for children who have gained the ability to play around the lit-up house instead of having to wander off to seek lit up environments or household members gaining access to entertainment at home rather than outside. Light used to be available before the adoption of a SHS, however, it was either unreliable or produced smoke which would prevent or limit the performance of some activities, mainly due to discomfort. A significant change in lighting sources used in the household is demonstrated in Figure 5.18 below. This change supports the energy ladder concept in that there is a noticeable elimination of traditional lighting fuels which are replaced by a SHS. Only 6 respondents had used a solar lantern before adopting a SHS, which is a relatively small number to support the solar energy upward movement concept from smaller to bigger off-grid solar solutions.



	SHS	Kerosene	Candles	Batteries	Grid	Other SHS	Solar lantern	Phone light
Lighting in the Household Prior to current SHS	0.0%	43.8%	37.4%	48.7%	3.4%	1.5%	2.3%	0.8%
Lighting in the Household Post current SHS adoption	98.5%	0.8%	0.4%	4.2%	0.8%	0.0%	0.0%	0.0%

Figure 5.18. Lighting sources used in the sampled households before and after adopting the current SHS (n=265).

However, the same movement as in the case of lighting sources is not observed in the case of cooking, not currently supported by SHSs, which implies that the ability to access a modern source of electricity does not go hand in hand with moving on to modern cooking fuels as well. Figure 5.19 below shows the common cooking fuels in use.



	SHS	Wood	Charc oal	Keros ene	Biogas
Cooking fuels in the HH Prior to current SHS	0.0%	93.6%	27.5%	0.0%	0.8%
Cooking fuels in the HH Post current SHS adoption	0.0%	94.0%	20.4%	0.4%	0.8%

■ Cooking fuels in the HH Prior to current SHS ■ Cooking fuels in the HH Post current SHS adoption

Figure 5.19. Cooking fuels used in the households before and after SHS adoption (n=265).

A slight drop is noticeable in the use of charcoal, but no other significant shifts are present between the before and after scenarios. Firewood is most commonly utilised which results from its availability, accessibility and low to no cost when compared to alternatives. The presence of different cooking fuels in addition to the lighting sources including a SHS support the energy stacking practice, where various energy sources are used at the same time, for the same or for different purposes (Masera et al., 2000; Baiyegunhi & Hassan, 2014).

The change in lighting sources from kerosene, candles and batteries to SHS supports the energy ladder concept (van der Plas & Hankins, 1998) as users move from an inferior source to a superior one when it becomes available. However, a number of households in our sample have adopted a SHS after having access to the grid network, which suggests a step down the energy ladder. The motivations for that were two-fold among the 9 respondents: firstly, the grid connection was unreliable and with frequent blackouts they would often be left with no electricity and therefore no light in the house, which would force them to resort to candles, kerosene or torches to light their houses at night; secondly, with regular power surges, the grid connection is perceived as dangerous due to the risk of electrocution, which was of particular concern among study participants with children.

Irrespective of the dichotomy of upward and downward movements, the evidence points to energy stacking behaviour apparent in the utilisation of multiple cooking fuels and lighting sources, whether at the same time (e.g. grid and SHS) or at different times (e.g. torches, candles or kerosene on occasions when SHS does not function or grid black out takes place). Jointly, the complex energy use conditions support the theory that even as households gain access to more modern energy sources, multiple fuels remain in use.

Having a modern and reliable source of lighting creates an overall feeling of improved well-being and safety (Parikh et al., 2012; Hirmer & Cruickshank, 2014; Harrison & Adams, 2017), both in respect to decreased fire hazard from candles or kerosene lamps, potential electrocution from the grid system (among the 9 households with grid connections prior to adopting a SHS) and outdoor and indoor safety at night, allowing more ease of moving around one's property and to deter external hazards such as thieves or wild animals. Fire hazard and smoke reduction might, however, be compromised by the continued presence of polluting sources used for cooking (whether firewood or charcoal) in the household.

Reliable and clean lighting is the most basic service that comes with a SHS and is available to all customers. It is responsible for a considerable proportion of practice changes. However, practices emerge and are rearranged not only as a result of having access to a cleaner, more reliable and safer source of lighting than prior to system adoption, but also due to the discontinuation or substitution of pre-existing practices (Lipschutz, 2015). A notable example is the need to go out to purchase light sources (candles, kerosene or batteries for torches). Time is saved as those trips no longer have to be made which creates time for other practices to emerge or for the rearrangement of existing ones. As one practice disappears- the going out to make the purchase, another one emerges- the making of the monthly payment for the system. The system payment, however, can be done via a mobile phone for customers using mobile money (minimal time required) or at a local mobile money agent or a bank, which also requires a certain amount of time to complete but only takes place once a month. As majority of adopters move towards the ever more prevalent mobile money technology (UNCTAD, 2017), this need will eventually be eliminated altogether.

Given the ubiquity of mobile phones in Rwanda, and many other Sub-Saharan African countries (David et al., 2015), the need to charge them exists for the majority of those who adopt SHSs. In our survey and workshops all participants owned at least one mobile phone per household, and frequently more. Next to having light, being able to charge mobile phones is an important motivation for purchasing the system. 48.3% of survey respondents mentioned it as one of the key motivations for purchase. Having a SHS moves the practice of charging phones externally at a shop or a charging station (at a relatively high cost of RWF50-100 per charge) and brings it into the home, allowing for more flexibility of when to do it and eliminating the need to take a trip out to have it charged, similarly as in the case of purchasing lighting fuels. Both constitute another spatio-temporal practice change. They also reduce the risk and inconvenience of running out of a lighting fuel or phone battery.

As discussed in earlier sections, having access to a source capable of charging phones, some customers have started charging them for others (e.g. neighbours or friends). Out of the 73.2% of respondents who said they were doing it for others (mainly family, friends, and neighbours), 11.2% said they were offering it at a charge. Majority would not charge anything, and a few said they would charge but only sometimes. In addition to the new practice (in-household mobile phone charging) triggering income making opportunities, practices of other individuals or groups have been impacted as well by changing the location where they have their phones charged.

Although most practices are routinised and performed without conscious decisions being made each time prior to performing them, Gram-Hanssen (2014) argues that conscious decision can also influence practices, of which the above could be one example. What is distinctly different in the case of low-income households relying on off-grid electrification is that the coming together of what Shove (2017) refers to as "devices, infrastructures and resources" might be limited to fewer devices or resources as a SHS has a capped capacity (depending on the panel and battery size) and typically there are only basic appliances that come with it, such as lights, radios, phone charging ports, with appliances such as TVs, fans, shavers and others being rare, and not always readily available for additional purchase, depending on the range of appliances offered by any given provider whose services the users are subscribed to.

As follows from the above, energy consumption is a non-linear process which does not consist of a single practice but rather of several different practices related to one another both vertically and horizontally, with changes in one practice affecting other related practices (Gram-Hanssen, 2011), also among users of SHSs as demonstrated in this study. Each appliance carries with it a potential to impact on a variety of existing practices and the creation of new ones. Mobile phone charging, for example, can only be performed if phone chargers are available, while TV entertainment is only available to those who own a TV or have an easy access to one. As much as practices that emerge, change and contract as a result of the shift towards a modern energy source depend on the appliances that are available, making up the *material objects* of energy use, it is the intensity of use, or the *procedures*, rather than the number or diversity of appliances that dictates the amount of energy used in the household. The maximum value for money, in our study, is achieved in the Group with the lowest number of appliances and the highest average income generation from the most common productive use of the appliances and practices changes- in-household phone charging. This could have implications for the off-grid energy sector to gain further insights into what practices (whether emerging or changing) drive the highest energy use and where income generation falls in the landscape of off-grid energy transitions. It should also be acknowledged that although the increase in appliance ownership does not immediately or automatically boost the economic well-being of households relying on SHSs for energy access, it does create more opportunities for practice shifts which have the potential to improve the overall well-being of household members, changing and expanding the *meanings* of having access to energy. It offers new services beyond the basic ones, thus fulfilling individuals' and household other existing needs and aspirations and allowing them to climb up the 'energy services ladder' (Sovacool, 2011). This could also be seen as a climb up the 'development ladder' or 'aspirations ladder', which is linked to the climb up the solar energy ladder in that it requires additional appliances beyond the basic ones, which are the most prevalent among SHS users.

5.1.4 Use and experience of services

The use of the systems with their appliances, which provide services such as lighting, phone charging, access to information and entertainment (radio and/or TV) is one way in which SSHS adopters use the services as offered by the provider. This aspect of the services relates directly to the energy devices (i.e. the physical product) and the energy carrier (i.e. solar energy) which the product relies on. The other aspects of energy services include the after-sales support which can be accessed via different platforms, including directly at the shop, via a dedicated Customer Service Call Centre (CSCC), a technician or a sales agent, although the latter two are not direct ways of receiving support in case of problems but rather provide an avenue of being directed to where help can be sought[36]. After-sales support incorporates issues of dealing with technical system problems, repairs and replacements of broken or malfunctioning parts (e.g. battery, appliances etc.) and assistance with making payments or other payment-related issues (e.g. delayed payments), as well as any other queries the customer might have.

Most common ways of interacting with the provider in different groups (according to a range of socio-economic characteristics) have been examined, followed by the perceived helpfulness (or lack thereof) of those interactions, as well as the overall perception of the delivery of energy services.

Survey participants most frequently interact with BBOXX via the CSCC and directly at the shop (the retail point), and less frequently via a technician or a sales agent, as shown in Figure 5.20 below.

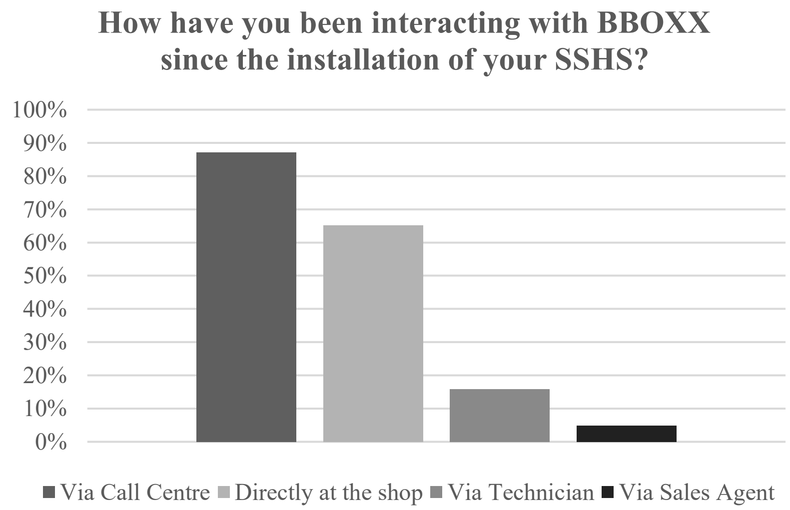


Figure 5.20. Most common ways of interacting with BBOXX among survey respondents (n=265).

[36] The role of technicians, who are responsible for installations and repossessions of systems, and sales agents, who are responsible for sales in their designated region, is not to provide after-sales support to customers but they can direct them to the CSCC and/or shops for support.

Fewer women than men have been interacting with BBOXX via their CSCC yet more have reached out directly at the shop in comparison to the proportion of men who have done so, as is shown in Figure 5.21.

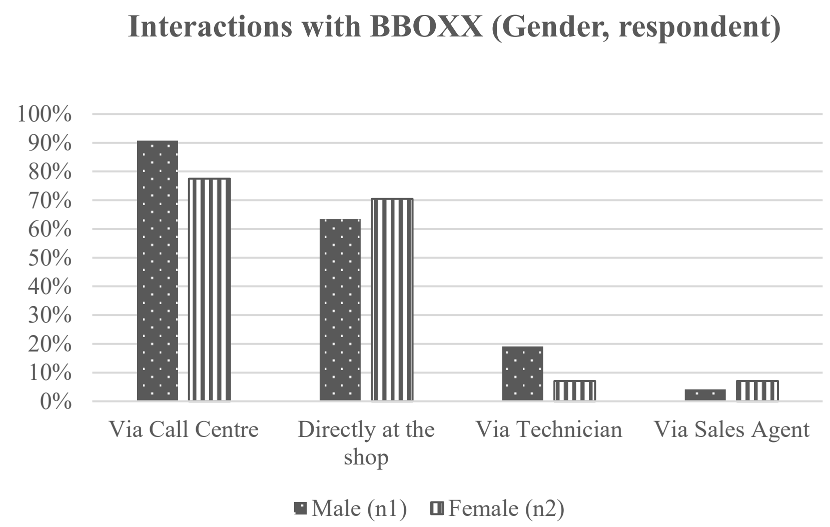


Figure 5.21. Most common ways of interacting with BBOXX by gender (respondent) (n1=194, n=71).

Despite the differences not being significant, when looking at the interactions with the provider among the three time-related Groups (1,2 and 3), the results reveal that those who had adopted a SSHS more than a year ago at the time of the survey, on average interact with BBOXX less via the dedicated CSCC than those in Groups 2 and 3 and more via seeing a BBOXX representative directly at the shop than those in the other two Groups. This difference is visible in Figure 5.22 below.

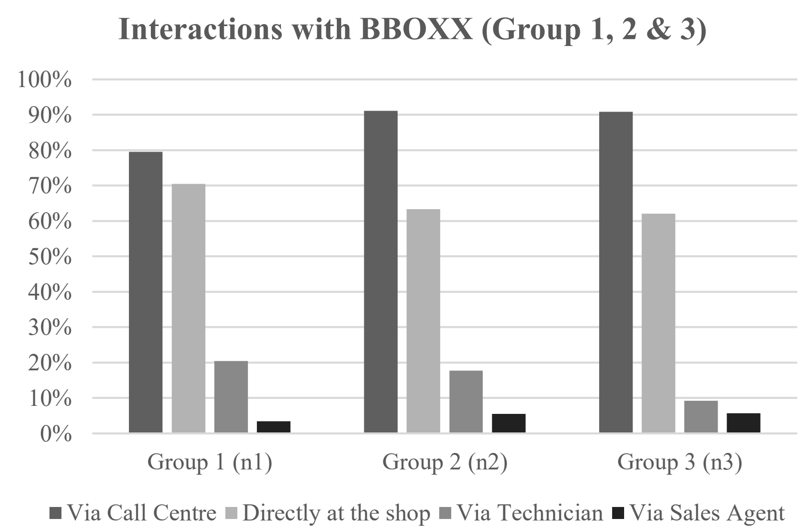


Figure 5.22. Most common ways of interacting with BBOXX by Group (1,2 and 3) (n1=88, n2=90, n3=87).

With an increasing number of customers across the country, the role and importance of addressing service needs has increasingly been falling on the CSCC over the years. Messages communicated to the new customers have also been changing and have impacted on the developed preferences of contacting BBOXX with any queries. Those messages and differing instructions customers were given when first interacting with BBOXX (whether at the time of purchase or installation, which is when guidance on whom and how to contact are provided) would have had an impact on the development of their preferred practices of contacting the provider for assistance. The growing importance of the CSCC and the stress on directing customers to it with any enquiry have increased the likelihood of more customers using the CSCC service. A factor which could be assumed to determine seeking support directly at a shop is distance from the grid line which often correlates with the distance from the main road where the shops are typically located. However, no correlation has been observed between the two variables ($r=-.001$, $p=.985$, $n=265$). Interactions at a shop, however, are impacted by the need of a customer to have a CU, its component or any system component or appliance replaced, as he or she is then required to bring it to the shop. There is, however, no data that was collected through the survey to test this relationship. Yet users who experience technical difficulties, regardless of their distance from the shop or their remoteness, are more likely to use the provider's services at one of their shops than those who do not.

Respondents were overall satisfied with their interactions, finding them always helpful (79.6%), sometimes helpful (12.1%), with those finding them mostly unhelpful (3.8%) and never helpful (4.5%) making up less than 10% of participants. Among those who found them unhelpful, majority of interactions were via call centre and directly at a shop. However, those interactions were also mostly appreciated among those who found their communication with the provider helpful. BB Lights and BB TV owners were the only ones among those who found the interaction to never be helpful, and with one other participant who owned an Ikaze SSHS were the ones who also found it to be mostly unhelpful. Owners of all other packages generally found their interactions with BBOXX helpful.

A broader question was asked to survey participants and discussed with FG1s participants, not focusing specifically on the ways they have been interacting with BBOXX but rather on the overall perception of the services that are provided, taking into consideration the different aspects, as mentioned at the beginning of this section. By not asking for one specific aspect of the services, and by following up with a question that gave an opportunity to elaborate on the answer, respondents and discussion participants could choose the aspect that mattered to them the most, also reflecting what customers understand *services* to be and what *good services* are in their view. Figure 5.23 below shows the split between survey respondents who either felt the services provided BBOXX were good or not, and a small proportion of respondents who did not have an opinion/did not know.

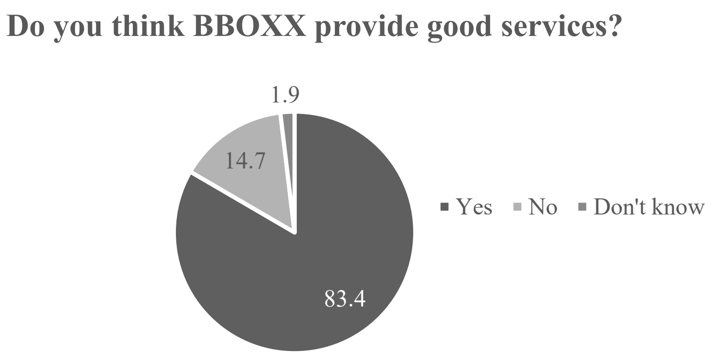


Figure 5.23. Survey respondents' perception of the services provided by BBOXX (n=265).

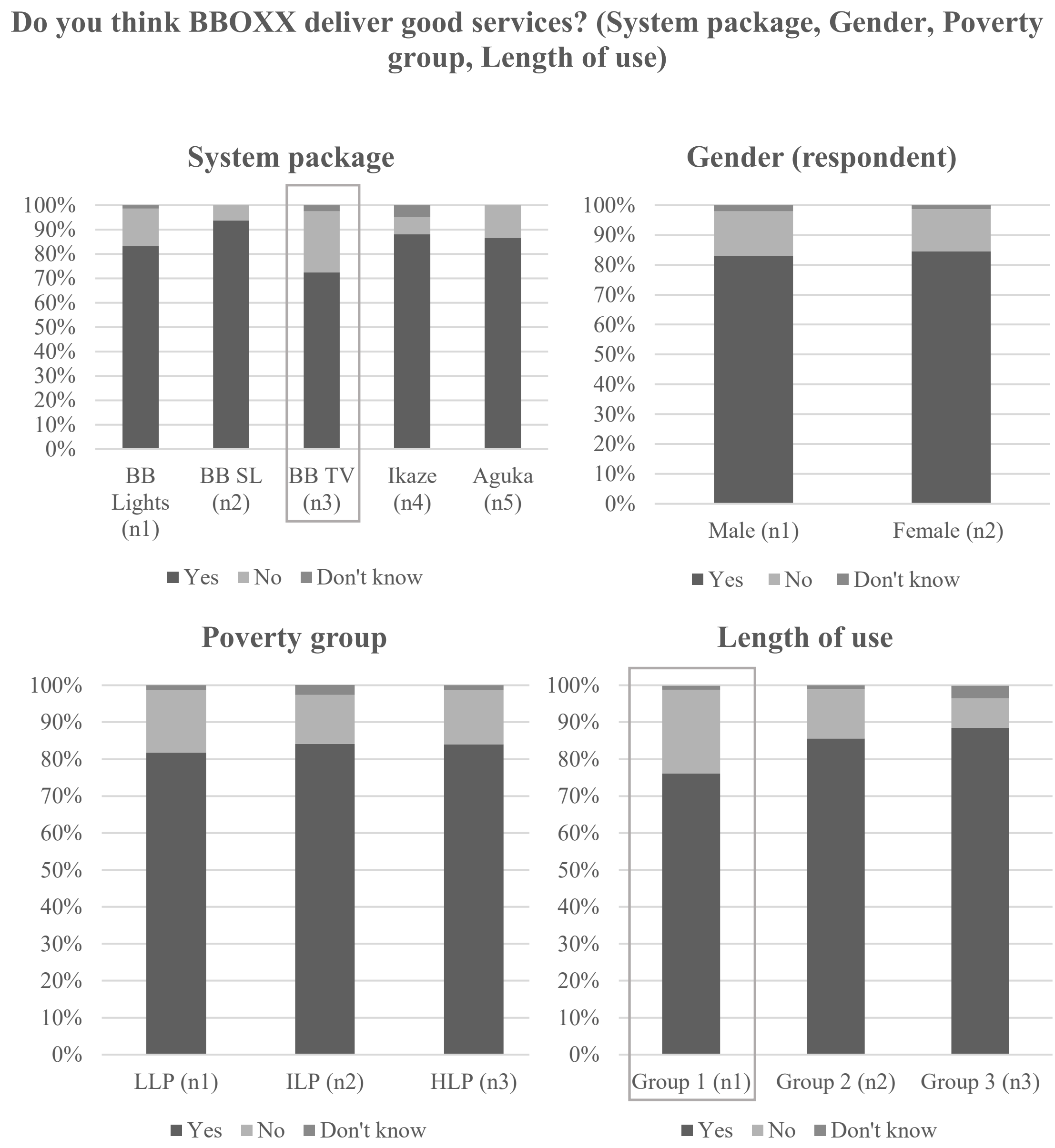


Figure 5.24. System package: n1=137, n2=16, n3=40, n4=42, n5=30; Gender (respondent): n1=194, n2=71; Poverty group (LLP, ILP, HLP): n1=77, n2=113, n3=75; Length of use (Group 1, Group 2, Group 3): n1=88, n2=90, n3=87.

The above Figure 5.24 gives the breakdown of survey respondents' answers to the question on whether or not they thought BBOXX delivered good services, split by different categories. Overall, a positive perception of those services is prevalent, with higher proportion of 'yes' responses across all categories. However, two instances of below average positive perception of the services can be observed among BB TV owners and respondents in Group 1, which is also the one BB TV owners fall under. This is compatible with the previous question on the quality of the interactions customers had with BBOXX and whether they found them useful, where BB TV and BB Lights owners were the majority who disagreed, saying they mostly or always found them unhelpful (first chart in Figure 5.24 also shows BB Lights owners with an average lower proportion of 'yes' responses than among BB Super Lights (BB SL), Ikaze and Aguka owners). The perceived drawbacks of the services provided, stemming from the experience of using them, fall under the following categories Table 5.5):

Customer Service (CSCC, (at the) shop, Sales Agent and Technician)	Product	Payments
• Difficult to get through to a CSCC operator • CSCC unhelpful • Lack of representatives on the ground to hear concerns • Shop staff unhelpful • Shop too far • Sales Agent/Technician unhelpful • Upgrade (adding an extra appliance) refused	• Faulty part replacement issues: lack of part availability, no pick up of faulty parts available • No TV signal • Short battery life (rainy season) • Not all energy needs met	• Price too high • Short grace period and switch off after delaying payment • Lack of appreciation for irregular income causing payment delays • Delayed switch on after making payment • No ability to pay at the shop (as initially) • Energy Service Fee (ESF) too high/not desired

Table 5.5. Categorisation of the perceived drawbacks of services provided by BBOXX according to survey respondents and FGs participants.

The above points of service dissatisfaction were also raised by FG1s participants. Customer services in the form of direct interaction with a company representative, product-related services (delivery of sufficient power, product (or energy device) functioning etc.) and the payment-related services (such as mode of payment and switch on/off for late payments) were the three most commonly mentioned ones. TV signals among TV owners were the most common challenge. It is partly the responsibility of the provider (making sure the antenna is strong enough and of good quality) and partly the responsibility of the TV service provider who oversees making sure the coverage of the TV signal in the area is sufficient. Signal problems had an impact on the lower levels of service appreciation among TV owners, who also felt they should no longer be required to pay the price for a TV while they are unable to watch TV channels on their set. The other use available to them was watching their own content which they can access through a USB drive. Customers in Group 1, at the time they purchased their system, were able to make their payment at a BBOXX shop, however, that changed when mobile money payments were rolled out and shop payments discontinued. To those customers who were used to the previous mode, the change meant that they were no longer able to track the status of their monthly payments by collecting physical receipts, which were considered reassuring in record keeping. Mobile money payments included receipts sent to the users' phones, however, those unhappy with them saw them as confusing and not as easy to keep track of as the physical ones. Additionally, even though at the time Group 1 customers adopted a SSHS there was no Energy Service Fee (which was introduced in section 2.4), it was introduced in early-mid 2016 which caused discontent among customers who purchased the system thinking they would own it at the end of three years, with no further payments. The confusion caused by the initial ways this change had been communicated to the study participants aggravated the problem. The lack of clarity on who was required to continue payments within the ESF scheme and who was not (customers who purchase their systems at the time the ESF was not in place yet were not required and signing up for it was optional) made it challenging for both survey and FG1s participants to understand the rationale and working of the Energy Service Fee. As put by a male survey respondent from Gasiza:

> "I signed up for a warranty [ESF] without knowing and I don't like it." (Male respondent, S3, Gasiza)

Another male survey respondent from Kidaho echoed the above feeling in saying:

> "I signed for a warranty [ESF] without knowing and I do not agree with it, I would like training on terms and reference of the agreement." (Male respondent, S2, Kidaho)

However, despite the ESF being met with a backlash from both survey and FG1s participants who purchased their systems before the ESF was introduced, 2 female PPWs participants (PPW3 and PPW19) and a small proportion of survey respondents (approx. 5%) who expressed concern that they would be left without assistance in case something happened to their system after the three years, once the system is repaid. A female PPW3 participant shared her concern and appreciation for long term service provision:

> "The particular thing that BBOXX has as compared to other companies is that those companies after three years - everyone will have to pay for faulty appliances and it's a lot of money, but us - we will still be paying 2,900 per month and if the appliance breaks you will replace it without having to buy it." (Female participant, PPW3, Muhanga)

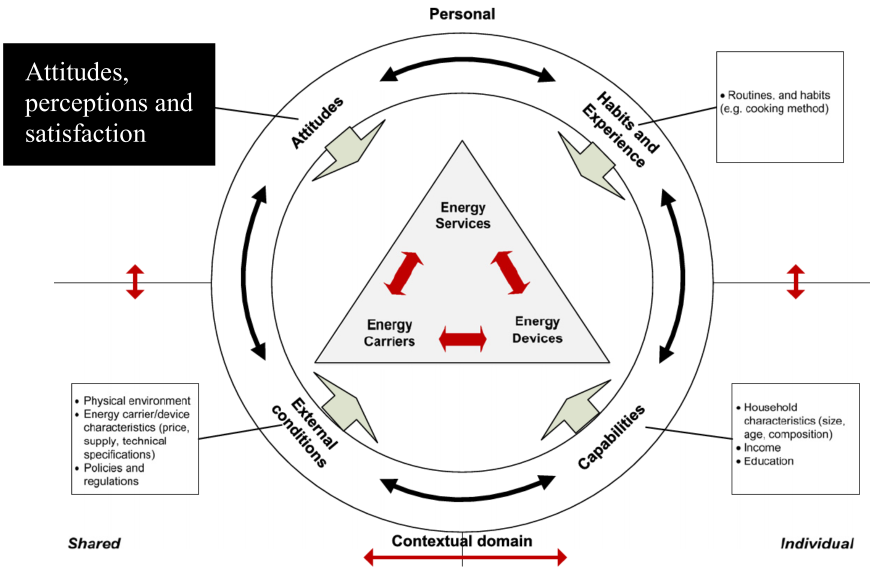
Regarding payments, flexibility of payments was a common issue mentioned by customers from all different groups falling under different categories. The main reason for it was the irregularity of income which makes it difficult to always pay on time. The willingness to pay would not always be matched with the availability of funds, either because the income comes at times which do not align with the set date of payment[37] or due to unexpected or temporary circumstances or conditions which might inhibit the ability to pay. This is reflected in the comment made by a male survey respondent from Kabaya:

> "We would like them [BBOXX] not to switch off our system when we delay paying because most of the time it's because we are sick." (Male respondent, S2, Kabaya)

The proportion of respondents who were happy with the services and considered them to be good expressed their appreciation of three main service points: always receiving support when it is needed, including the replacement of faulty appliances and other components; the product working well/no experience of problems with the system; and their needs being satisfied. This will be further discussed in the following section where attitudes towards solar energy and SSHSs, as well as satisfaction with the quality of energy services and devices will be the focus, along with the exploration of study participants' needs and aspirations, which in part makes references back to the challenges associated with the offered services, discussed above and further discussed in section 5.4.6.

[37] Customers were required to always pay on the same day of the month, depending on the day of their first payment. This could be a day of the month of various degrees of convenience. However, this has since changed to offer higher flexibility of payments. At the time of the study, it remained a challenge for a proportion of participating SSHS users.

5.2 Attitudes and satisfaction



5.2.1 Knowledge of solar

When asked about how much they know about solar energy and the technology around it, 80% of the survey respondents said they know little or very little. The novelty of it and the fact that it is still relatively rare and not present in all regions in Rwanda, and certainly not all villages, means that households have generally had little exposure to SHSs, with their own experience and knowledge built from using their own system constituting the bulk of their knowledge on what solar technology is and how it functions. The general idea that it is powered by the sun and that the panel is what captures the energy is well-comprehended, however, the details of how it is converted into electricity are less known. It is, however, commonly perceived as safer than the grid as there is no possibility of getting electrocuted, which is seen as superior. As put by a participant of FG1(1):

> "I know that the solar energy is safe compared to candles, it can't cause electrical shocks to children as it is with the grid, and it does not produce fumes." (Male participant, FG1(1), Nyarubuye)

In discussions with FG1(1-5) participants the question on perceptions of solar technology and, more specifically, the SSHSs which they use in their houses was explored. The sentiments shared spanned a wide range and included more positive, more negative and neutral. 3 different participants of FG1(2) expressed the below:

> "The technology is beyond our understanding." (Male participant FG1(2), Bigogwe)

> "We do not understand how they control remotely. We just charge our phones, we light up." (Male participant FG1(2), Bigogwe)

> "[…] I also do not understand how it captures solar energy." (Female participant, FG1(2), Bigogwe)

The remote monitoring and the ability to remotely switch on and off the systems is what the second male participant was referring to. Customers are generally aware that BBOXX have that kind of ability, but they do not know how it works. Among FG1(4) participants, many of whom experienced technical problem with their systems, the opinion on the technology was on the negative side of the spectrum, with one customer saying: "The technology is bad". The key reasons were: no TV signal, issues with batteries (charging and short lifetime when charged), and too few appliances, particularly lights. The view of the technology, in that case, was dimmed by the negative experience of using the system. In FG1(1) and FG1(5), the attitudes were on the opposite side of the spectrum. When asked about the technology, one participant answered:

> "The technical specifications are awesome. We were not sure when we would get electricity but now we have it! We can watch TV, light up the house…" (Male participant, FG1(5), Gakoro)

While participants of those two FGs had also experienced technical challenges (faulty appliances and battery issues), they received assistance when it was needed and were able to more objectively talk about their perceptions of the technology as the experience of encountering some challenges did not outweigh the recognition for the technology itself and what benefits (through the services provided) it offers. Knowledge of other Solar Home System providers among survey participants was limited. 34.3% had no knowledge of any other providers or sellers of SHSs other than BBOXX, while among the 65.7% who knew other providers, majority were familiar with Mobisol (73.8%). On average, they knew of one or two other providers (Figure 5.25). Private sellers (offering off-the-shelf purchases, often without warranties), including sellers of SHSs from Uganda (whether Ugandans or Rwandans selling Ugandan products) were the second most common off-grid solar solutions respondents were aware of.

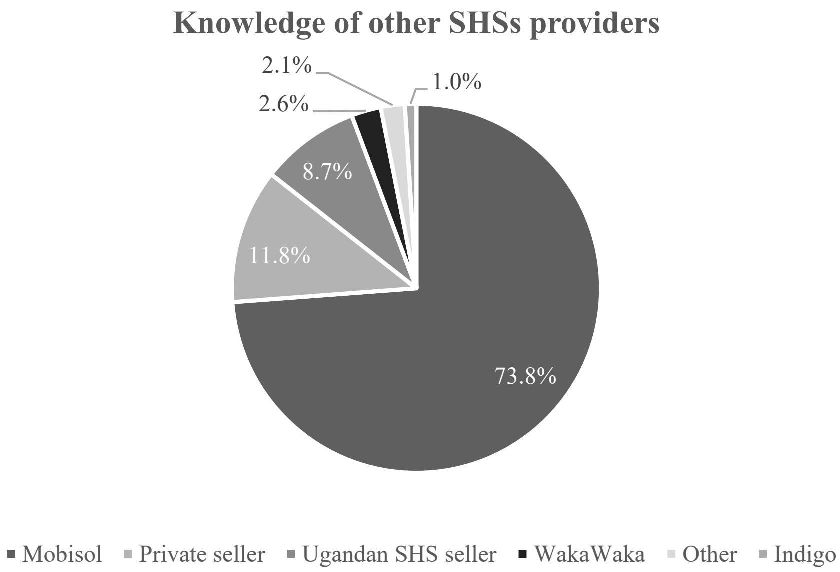


Figure 5.25. Other SHSs providers which survey respondents were familiar with (n=265).

Cross tabulating the question on the knowledge of other solar providers (other than BBOXX) and the shop area respondents belong to has revealed that those in the Kidaho and Kirambo shop areas are the two groups of customers familiar with sellers of Ugandan SHSs (as marked in Figure 5.26 below). These two shops (with their adjacent areas) are the closest ones from the Ugandan border (Kidaho is located less than 5km from the border and Kirambo just over 30km, with other 9 shops all farther away, for reference see map in Appendix 12).

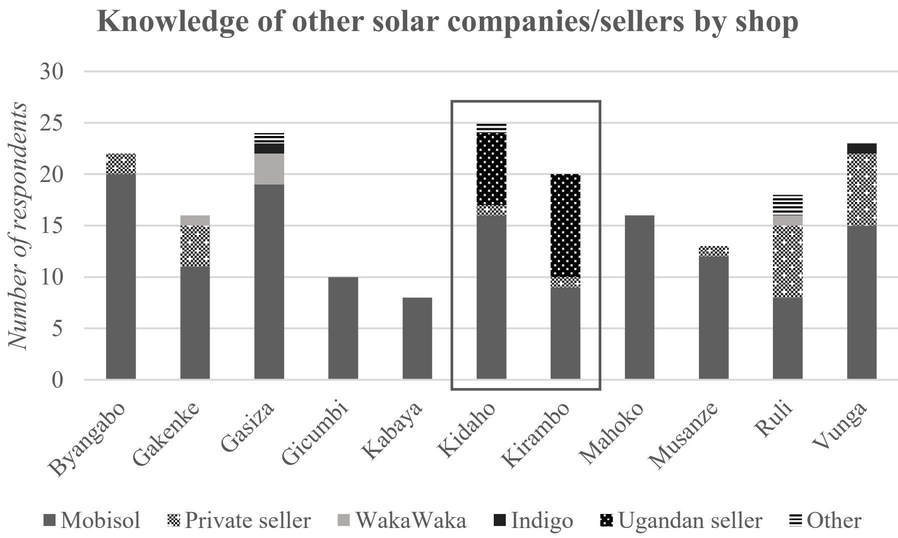


Figure 5.26. Other SHSs providers which survey respondents were familiar with by shop they belong to (total n=265).

While Kidaho and Kirambo were the two areas where respondents were exposed to sellers of SHSs brought in from Uganda (which is further discussed in section 5.2.7), respondents in all shops knew Mobisol and in 6 out of 11 shops were also familiar with private sellers (mostly off-the-shelf products). Respondents from Gicumbi, Kabaya and Mahoko reported familiarity with Mobisol only, which points to the domination of markets in those areas by BBOXX and Mobisol, with respondents from around Musanze (Ruhengeri), which is a major city in the Northern Province, showing familiarity mostly with Mobisol and only a few knowing private sellers, which also shows the two providers to have the most presence in that area.

5.2.2 Reliability of solar energy

The reliability of solar energy was generally perceived well. Nearly half of survey respondents thought it was 'mostly' reliable, while less than 5% thought it wasn't reliable (Figure 5.27).

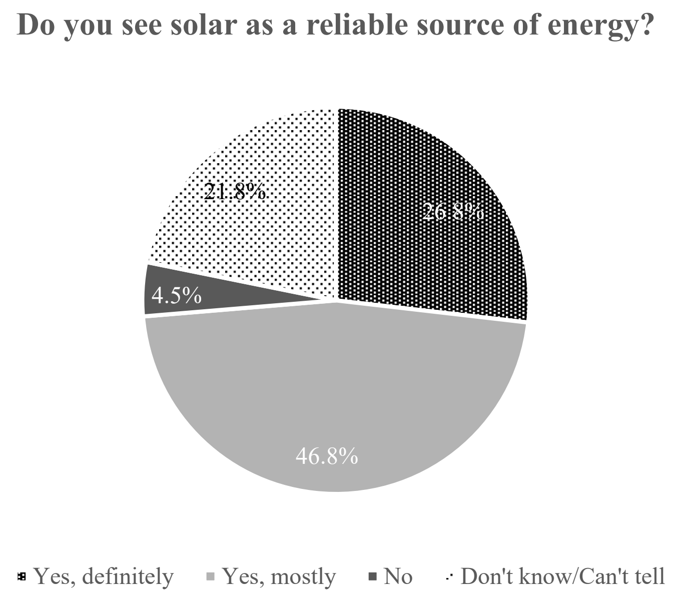


Figure 5.27. Perceptions of solar energy reliability among survey respondents (n=265).

Those who responded 'Don't know/Can't tell' were also among those who said they knew little or very little about solar energy. Time of use was not a determinant of whether or not solar energy was seen as reliable (x2=7.068, DF=8, p>.05) (Figure 5.28 below).

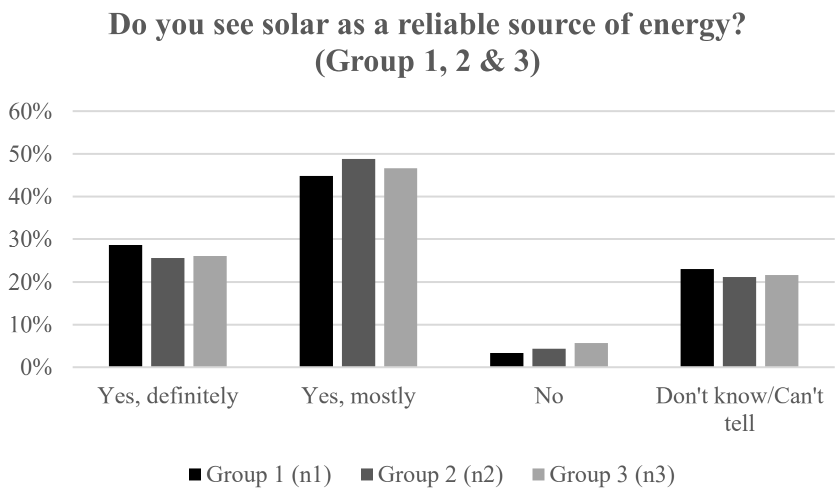


Figure 5.28. Perceptions of solar energy reliability according to length of time the system has been used for among survey participants (n1=88, n2=90, n3=87).

In all three Groups customers perceived solar energy to be ‘mostly’ reliable, with a marginally higher proportion (insignificant) of those in Group 1 saying ‘definitely’ reliable and a marginally higher proportion (insignificant) of respondents in Group 3 seeing it as not reliable. Among male and female respondents, the breakdown of answers was not as even, although gender was also not a predictor of how solar as an energy source was seen. Figure 5.29 below demonstrates the breakdown of male and female survey respondents

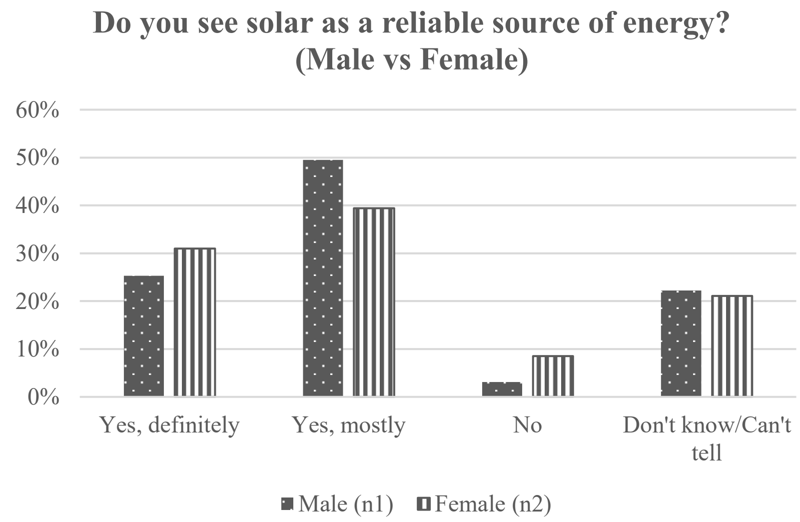


Figure 5.29. Perception of solar energy reliability among male and female survey respondents (n1=194, n2=71).

More women saw it as ‘definitely’ reliable and, at the same time, more women than men saw it as not reliable. More men saw solar energy as ‘mostly’ reliable as compared to women and an even number of men and women were unable to tell or did not know. The perceptions of solar energy among users of different system types also shows that the highest proportion of those unable to tell is not exclusively present among those who have Ikaze and Aguka and who have been using their systems for a shorter period of time. The tested assumption was that the shorter the time since adoption, the harder it might be to judge the reliability of solar energy based on a relatively short time of use. However, it was BB TV (Group 1) and Aguka (Group 3) customers among whom responses ‘Don’t know/Can’t tell’ were the highest, as shown in Figure 5.30 below.

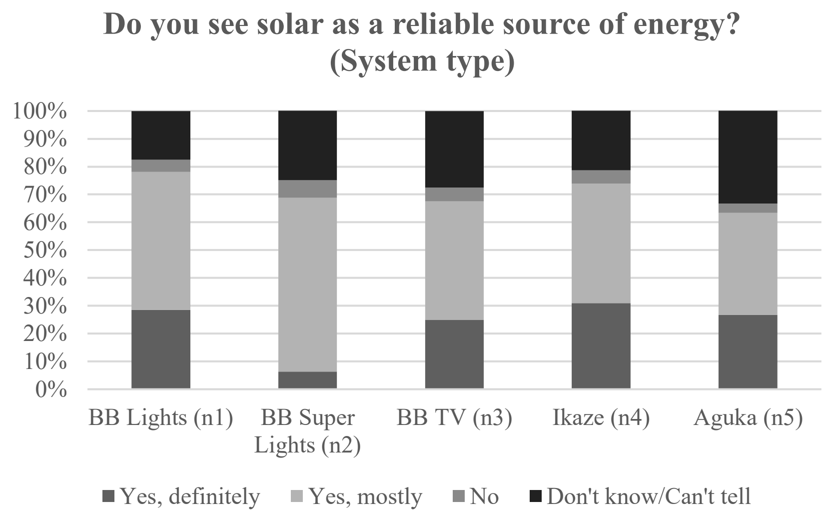


Figure 5.30. Perception of solar energy reliability among users of different system types (n1=137, n2=16, n3=40, n4=42, n5=30).

When discussing reliability of the system, FG participants had differing perspectives on what reliability meant for them. For some, it was a matter of being able to have all their energy needs covered by the SSHS which would make it reliable, as put by one participant (FG1(1)):

> "It could be reliable if we could afford to cover all our needs." (Male participant, FG1(1), Nyarubuye)

For another one, reliability was linked to safety and the capacity of the system:

> "For the safety we think that it is reliable, however, for the capacity, it is not when you need more lights, or doing other things [which we cannot do] if the system remains the way it is." (Female participant, FG1(2), Bigogwe)

5.2.3 Satisfaction with amount of electricity provided

Tied to the perception of reliability of solar energy in the case of SSHSs was the question on the satisfaction with the amount of electricity that HHs get from the system. Over 80% of all survey respondents were satisfied with the amount (either very satisfied or satisfied), just over 15% being on the dissatisfied end of the scale. Figure 5.31 below demonstrates the split of responses.

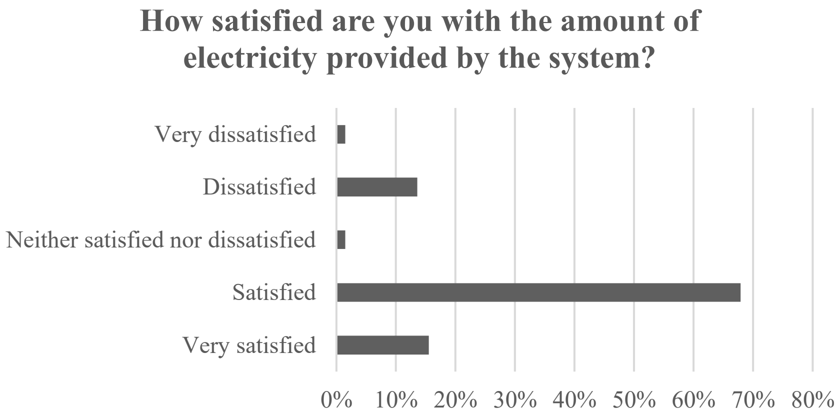


Figure 5.31. Satisfaction with the amount of electricity provided by the SSHS among survey respondents (n=265).

While a considerably higher number of respondents were satisfied with the amount of electricity provided by their SSHSs, the number of those who felt it could provide enough electricity for their HHs now and in the future was lower, at 42.3% (n=265). 24.2% thought it cannot provide it (Figure 5.32).

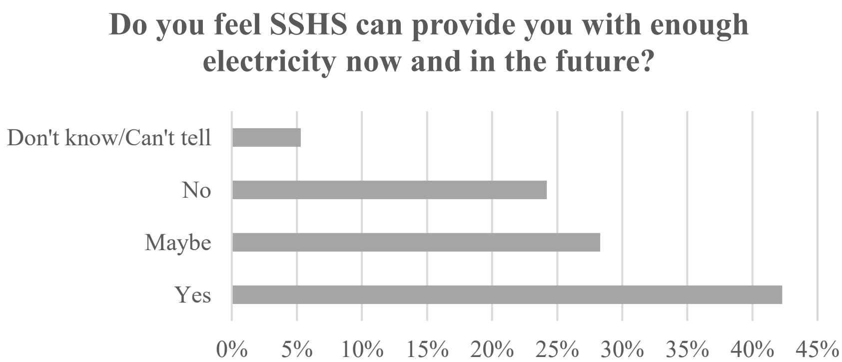


Figure 5.32. Survey respondents' perception of the ability of the SSHS to provide HHs with sufficient electricity now and in the future (n=265).

After cross tabulating the two above questions (results shown in Figure 5.33 below), a a significant relationship was found (x2 = 21.129, DF=12, p=.049). Those very satisfied and satisfied were more likely to think their SSHS can provide sufficient electricity in their HHs now and in the future than those dissatisfied and very dissatisfied.

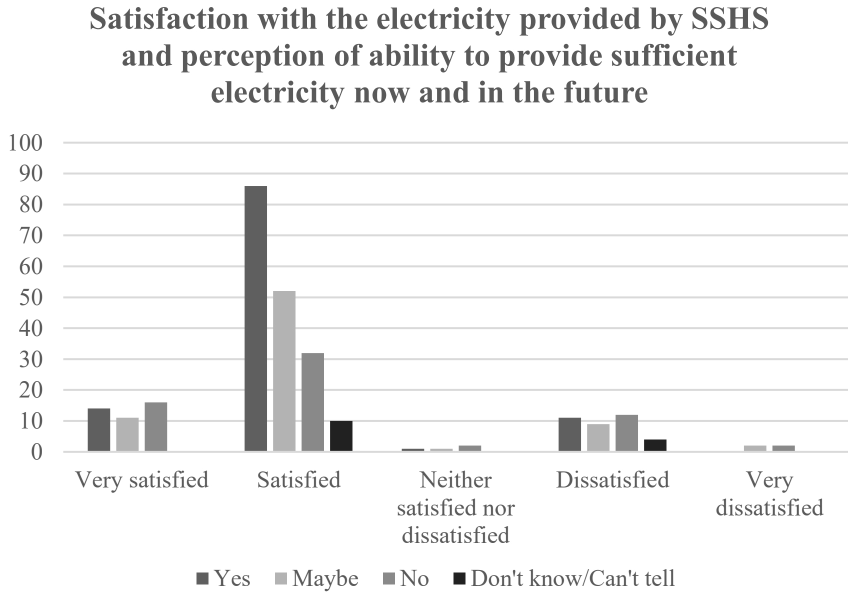


Figure 5.33. Number of survey respondents who think SSHS can provide them with sufficient electricity now and in the future by their levels of satisfaction of electricity provided by the SSHS (n=265).

Satisfaction with the electricity supplied by the SSHS between female and male respondents showed very similar levels of satisfaction, with a higher satisfaction, on average, among men than women, and a slightly higher dissatisfaction expressed by women than men (Figure 5.34). More women were also undecided ('Neither satisfied nor dissatisfied').

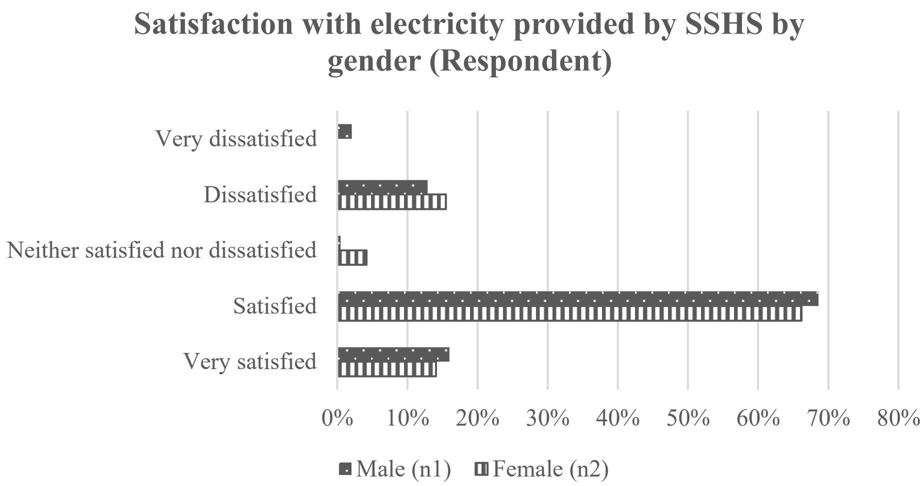


Figure 5.34. Satisfaction with the amount of electricity provided by SSHS among male and female survey respondents (n1=194, n2=71).

The highest proportion of those very satisfied and satisfied with the amount of electricity provided by the system was among Aguka and BB Lights users respectively, whereas Ikaze users had the highest percentage of dissatisfied customers. Figure 5.35 below shows the breakdown.

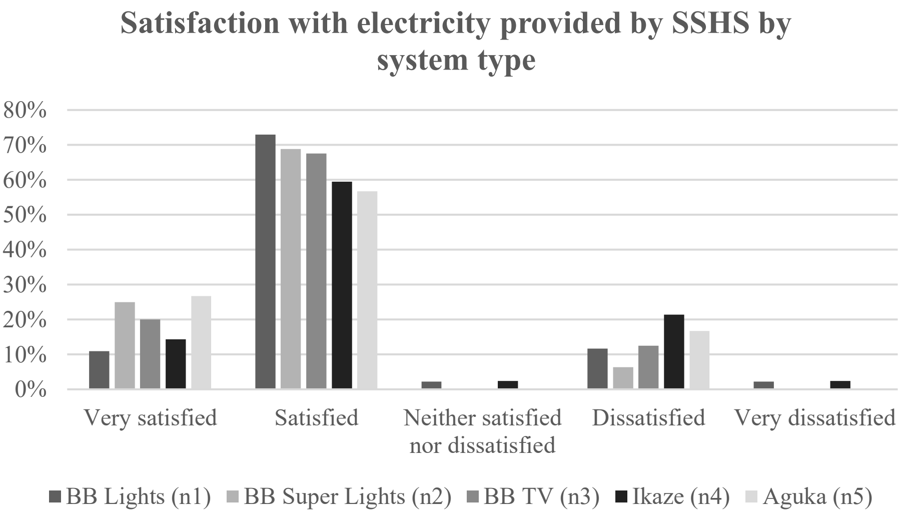


Figure 5.35. Satisfaction with the amount provided by SSHS by system type (n1=137, n2=16, n3=40, n4=42, n5=30).

The above results demonstrate that satisfaction with the amount of electricity provided by a SSHS is not higher among those with fewer appliances. All three: Aguka, BB Super Lights and BB TV users have, on average, more appliances than BB Lights and Ikaze users yet they are among the top three of very satisfied (Aguka, followed by BB Super Lights and BB TV) and satisfied (BB Super Lights and BB TV as second and third respectively, preceded by BB Lights users) customers. The highest percent of

Ikaze users were dissatisfied among all system types, which is also not the groups with the highest number of appliances, on average.

Among the three Groups (1, 2 & 3) who have been using the system for various periods of time, Group 1 users (i.e. those who have been using it for the longest time) were, on average, the most satisfied with the amount of electricity provided by their SSHS (Figure 5.36). Only users of BB Lights, BB Super Lights and BB TV are present in that Group and the results corroborate results demonstrated in Figure 5.34 above where those with BB Lights, BB Super Lights and BB TV systems had, on average, 88.4% of satisfied users (very satisfied and satisfied combined), as opposed to those with Ikaze and Aguka systems at 78.6% average satisfaction (very satisfied and satisfied combined).

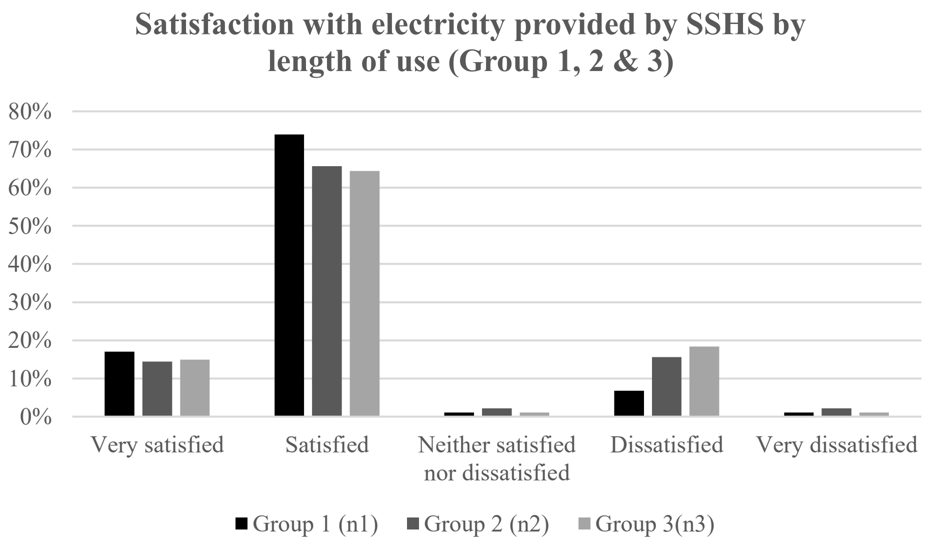


Figure 5.36. Satisfaction with the amount of electricity provided by SSHS among users in Groups 1, 2 & 3 (n1=88, n2=90, n3=87).

5.2.4 System quality

55% of all survey respondents found the quality of the SSHS to be very good or good. Just over 18% said it was poor and nearly 27% did not know or could not tell.

The main categories of both satisfaction and dissatisfaction with the system quality were the battery and the appliances. Figure 5.37 below shows a word cloud of the 100 most frequently used words used by survey respondents in justifying their responses about their perceived system quality, and the diagram (Figure 5.38) demonstrates the most common responses under the perceived ‘Good’ (combined very good and good) and ‘Poor’ quality of a SSHS. Among those who said ‘Don’t know/Can’t tell’, there was a triple split: those who had no opinion; those who couldn’t tell but had positive comments (included under ‘Good’); and those who had negative comments (included under ‘Poor’).

Figure 5.37. Word cloud demonstrating the 100 most frequently used words (min. 4 letters-long) used by survey respondents in answers to: “Why do you think the quality of the system is very good/good/or poor?” (n=265).

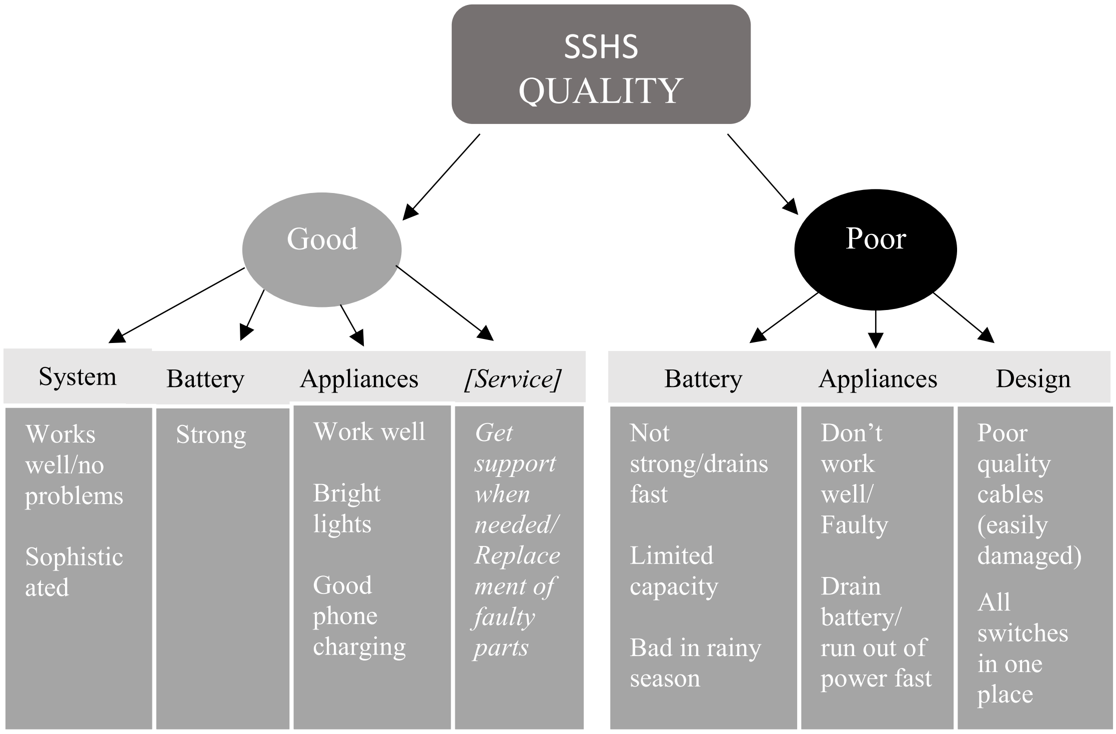


Figure 5.38. Perceived quality of the SSHS among survey respondents.

Those who found the quality of the system good or very good often referred to the above aspects: system (overall), battery, appliances, as well as support whenever there is a need for it, which is nested under 'Service' and marked in italics as it does not, per se, refer to the system quality, but rather (the quality of) the service provided. Yet it appears that it did matter among those who expressed content with the SSHS quality. Indirectly, by offering battery and appliance replacements, the service is part of the good quality experience as the system (with its components) continues to work well, hence the mentioning of that aspect of perceived quality. One of the survey respondents summed it up by commenting:

> "Appliances perform well, and they replace broken items." (Male respondent, S3, Ruli)

Those who found the quality to be poor mostly referred to the battery, appliances and the SSHS design. The weakness of the battery which demonstrates itself in the battery draining fast or not charging fully, which means it does not last very long, was also stressed among some of the FGs participants. One of them in FG1(5) said:

> "For the past months, my battery drains faster, and I am frightened of what will happen when I finish to pay [off], and [have] all the privileges taken away from, and the battery could not last even 2 hours of lighting." (Male participant, FG1(5), Gakoro)

The above respondent was also concerned about what would happen to his system after the 3-year repayment period, worrying that he would lose the warranty and the system quality would deteriorate, making it difficult or impossible to use. A similar concern was expressed by survey respondents, among them one pointed it out by when saying:

> "I don't know, I am afraid that after the 3-year guarantee they won't work again." (Male respondent, S3, Vunga)

That concern was shared predominantly by respondents and FG participants who had experienced technical difficulties with their systems and had to resort to getting support from BBOXX. Particularly those who had adopted a SSHS before the new ESF model was introduced were worried about the warranty services ending after 3 years. However, there were also participants from Group 3 (less than 6 months at the time of data collection) who expressed a similar concern and who were included in the ESF scheme, however, they had no knowledge of it/were unaware of it. This point will be further discussed in section 5.4.6.

Another participant (FG1(2)) expressed concern about quality, reliability and the amount of electricity provided, saying:

> "It does not provide enough electricity, as we have been told that we have to be cautious. And certainly, when there is no sun, we do not light up." (Female participant, FG1(2), Bigogwe)

The above also speaks to the way training was provided: "[w]e have been told we have to be cautious" in the use of the system, meaning that caution in how much and how long the system is used for might be impacting on the perception of insufficient amount of electricity provided. At the same time, the participant referred to the challenges experienced on cloudy/rainy days when the battery charge might be hindered by decreased irradiation.

When looking at the breakdown of perceived system quality among different Groups and system type users, the results are varied. With nearly 70% Aguka users (the highest proportion among all groups compared in Figure 5.39 below), seeing the quality as good and very good, they are compatible with the results on the question regarding satisfaction with the amount of electricity provided by the system where Aguka users were, on average, the most satisfied with that amount.

However, the same is not the case for BB Lights users, who were among the most satisfied with the amount of electricity provided together with Aguka users, but just over 50% of them perceived the quality of the system as good or very good.

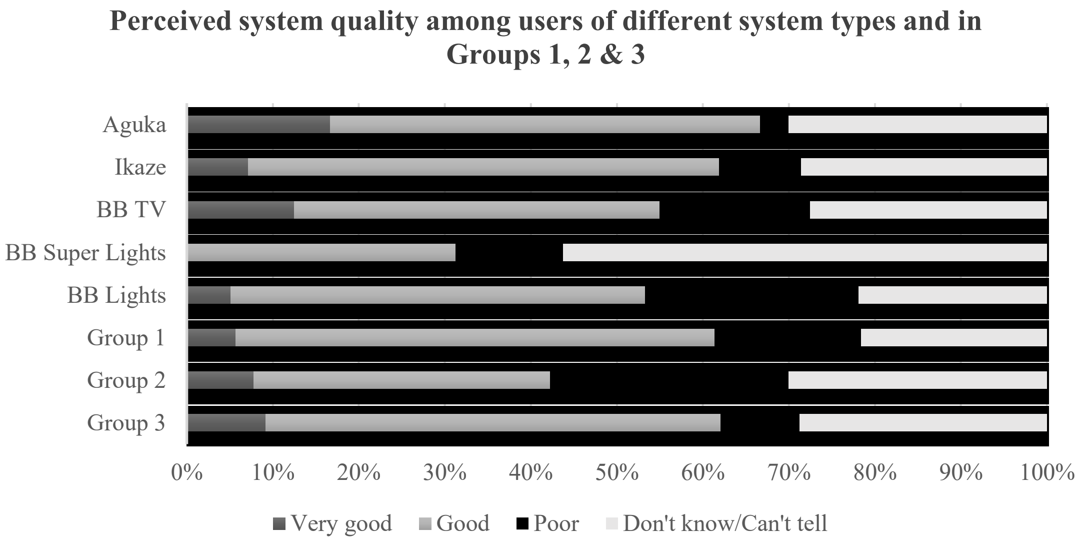


Figure 5.39. Perceptions of system quality among users of different system types and across Groups 1, 2 and 3.

Among Group 1, 2 & 3 users, over 60% of those in Groups 1 & 3 thought the system was of good or very good quality (61.4% and 62.1% respectively), whereas among Group 2 respondents 42.2% said they thought the system was of good or very good quality. Among the three Groups, they were also the ones who had the highest proportion of users who thought the system quality was poor (27.8% as compared to 17% in Group 1 and 9.2% in Group 3).

5.2.5 System price

The overall perception of the prices (they differ according to the system type and number of (extra) appliances which the customer has chosen) is that they are high. It was perceived as such among survey respondents regardless of the system type/package they had adopted: BB Lights (RWF6000/month) and Ikaze (RWF3900/month) which are the basic ones under the older and the newer model[38] respectively, and the BB Super Lights (RWF11500/month), BB TV (RWF14500/month), and Aguka (RWF5850/month).

7% of all survey respondents considered the SSHS to be very expensive, 48% expensive and 18% affordable, as shown in Figure 5.40 below. 27% said they did not know or could not tell, or they did not have an opinion on the pricing.

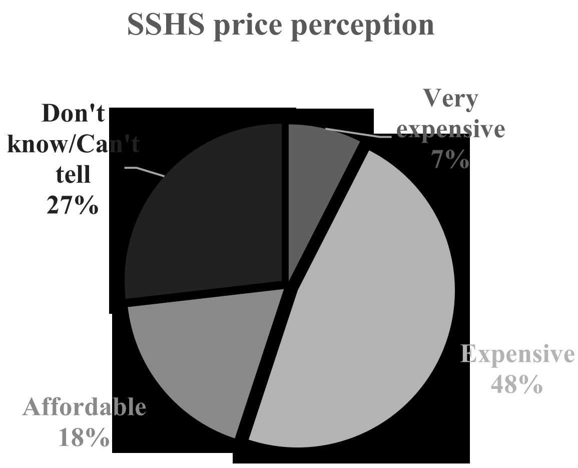


Figure 5.40. Perception of the SSHS price among survey respondents (n=265).

[38] It has to be noted that BBOXX have since changed the operating model for system types/packages and moved away from Ikaze and Aguka to more flexible purchases allowing an easier selection of desired appliances. For details of changes over time, please see Appendix 11.

Below Figure 5.41 presents the responses split by gender (male, female), poverty group LLP, ILP & HLP), length of use (Group 1, 2 & 3), and system type (BB Lights, BB Super Lights, BB TV, Ikaze and Aguka).

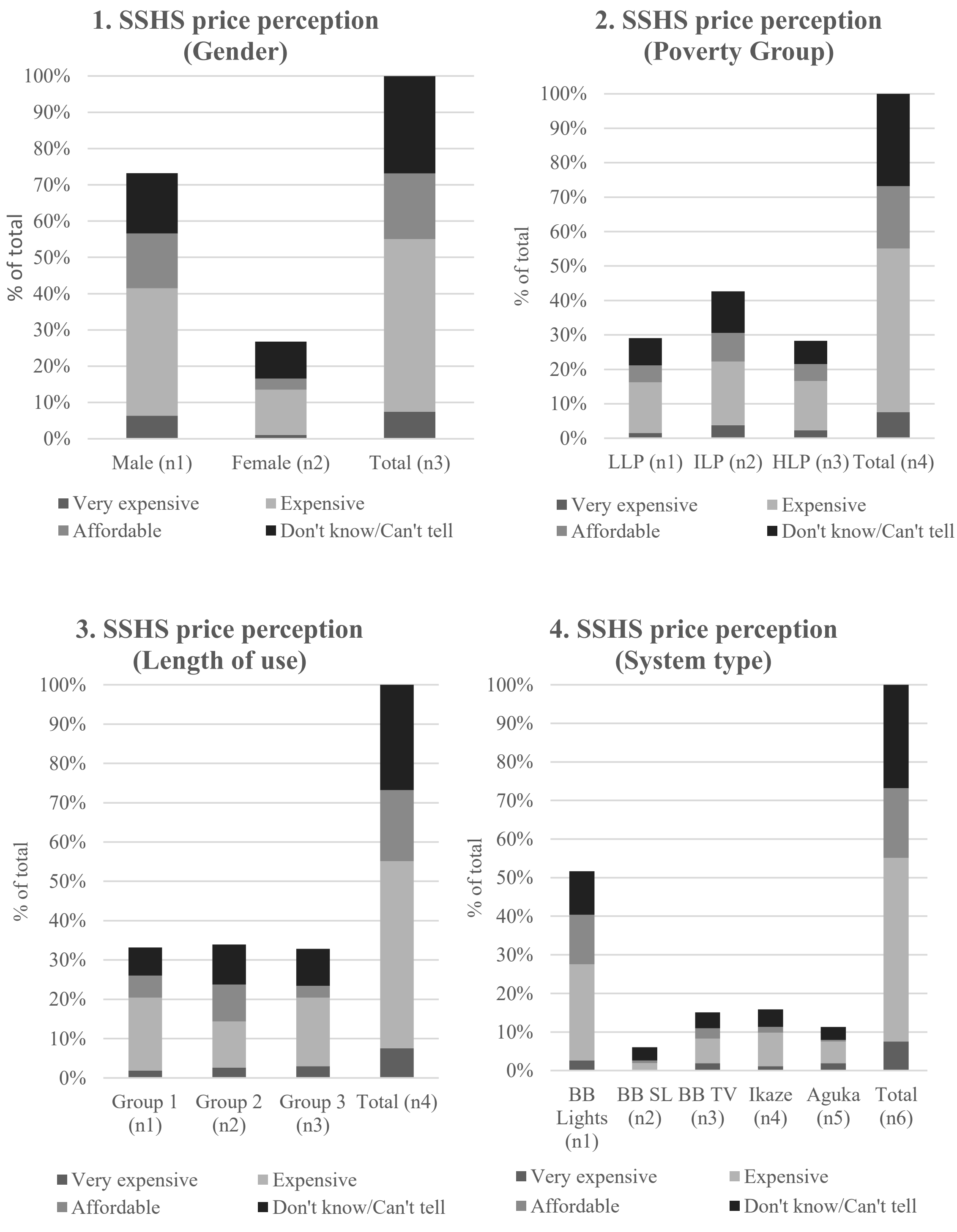


Figure 5.41. Perceptions of the SSHS price split by gender (respondent) (upper left) (n1=194, n2=71, n3=265); by poverty group (upper right) (n1=77, n2=113, n3=75, n4=265); by length of use (lower left) (n1=88, n2=90, n3=87, n4=265); and by system type (lower right) (n1=137, n2=16, n3=40, n4=42, n5=30, n6=265).

More men than women perceived the price to be very expensive (8.8% of the total number of men vs 4.2% of the total number of women), a similar number said it was expensive (47.9% and 46.5% respectively) and nearly twice as many men thought it was affordable as compared to women (20.6% and 11.3% respectively). Women were more often unable to tell or did not know/did not have an opinion on the price than men (38% of all women as opposed to 22.7% of all men).

The highest proportion of respondents who considered the price to be affordable was among Group 2 customers (27.8% of all Group 2 as compared to 17% among Group 1 and 9.2% among Group 3). Perception of price was not associated nor correlated with the poverty group. As shown in Figure 5.42 below, HLP group system users have adopted different types of systems (or system packages), including the highest percent of all BB TV systems (the most expensive ones) as compared to the other two groups (17.3% vs 15.6% in LLP and 13.3% in ILP).

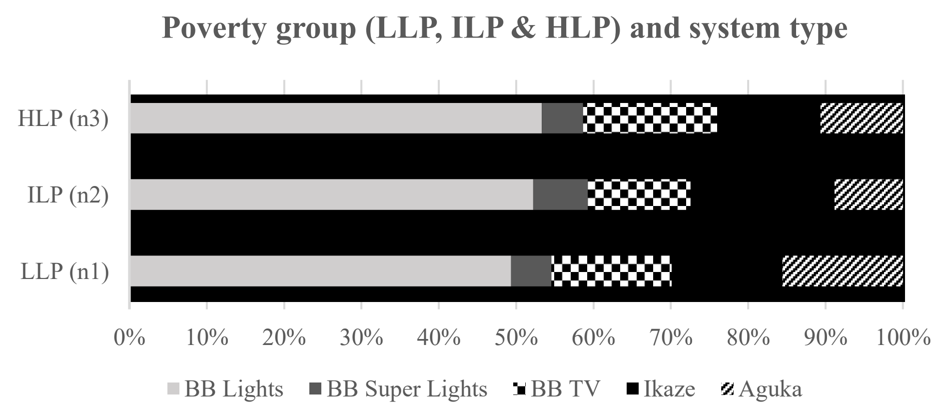


Figure 5.42. Adopted system type by poverty group (n1=77, n2=113, n3=75).

In all FG1s (1-5), participants stated that the prices were high and that they would like to have them reduced so they match their financial capabilities. Additionally, FG1(1) participants, as they all had systems which they adopted under the older package scheme (BB TV, BB Super Lights and BB Lights), expressed discontent with the fact that they were paying more than those adopting the systems under the new scheme (Ikaze and Aguka) while not getting the same level of service. Their expressed want was to pay at least the same prices as those under the new scheme. In FG1(3), there was a split between participants: two of them were willing to continue paying the same price as they were or even more as long as they get good services, whereas the other four thought the prices were too high and they would like to see them go down. Among FG1(4) participants, those with packages under the old scheme also expressed dissatisfaction with the prices they were paying compared to those adopting SSHSs under the new scheme, while others (those with the new packages) considered the prices to be affordable. There was a noticeable feeling of resentment among customers who had adopted their systems before the new packages came in, and the feeling of being treated unfairly as the services, in their opinion, were the same or less yet they were paying a higher monthly price than those who adopted their systems more recently.

In the second round of FGs (FG2(6-10) where in FG2(7) most participants were the same as those who participated in FG1(5)), participants were also unhappy with the prices. In FG2(6), the discussion on prices concluded with a statement, agreed on by all participants, that the prices were high and they all bought the system only because of the benefits it offers, not because they thought it was affordable. In FG2(8) and FG2(10) the affordability of the SSHS was compared to the prices of the grid connection and this is where participants agreed their systems were more affordable than the grid. Participants in FG2(9) were split: those who were using the PAYG mode of payment (not all customers, at the time, were yet transferred into this mode, some remained on the monthly mode of payment) considered the prices affordable as they were able to pay "little by little", as expressed by one participant. The others said it could be affordable if there were no aftersales services by which they meant the ESF post the 3-year initial payment period, after which Energy Service Fee would be applied (at the rate of RWF2900/month). Some of FG2(8) participants also shared a similar view. There were a few participants in FG1(4) and FG1(5) who had BB TV systems and whose TV sets did not work properly, yet they still had to continue paying the price for the TV package. A couple expressed willingness to downgrade their systems and give up their TVs, but it was impossible. For them, that issue was linked to affordability: they were not able to afford something they could not use. Even though they did decide to adopt TV packages initially, they were willing to pay for as long as they would get the full service they subscribed to. However, the lack of signal and/or faulty sets meant they were missing the most expensive and, for them, one of the most important services. Lastly, concerning prices and payments, customers who were already enrolled in the PAYG payments were not always aware of it. For those who were not or were not aware of it, it was sometimes difficult to pay on the day of the month which was determined depending on when they decided to adopt the system and made the initial down payment (which was a pre-requisite of having the system installed). It would always be the same day every month and the whole amount had to be paid, which, given the lack of regular income and the often-high variations in available cash throughout a month, made it challenging to have the amount ready on the required date.

The need for greater flexibility of payments was expressed, for example, by one survey participant who referred the need to adjust the payment mode to the seasonality of income:

> "I would like to [be able to] pay like three months during the harvest, I don't like the monthly payment system even people in our village also don't like it." (Male respondent, S2, Mahoko)

The payment flexibility challenge was addressed by introducing the PAYG model and for those who were already enrolled, at the time, it helped to complete the required monthly payment over several smaller payments, which they could make as and when cash was available in the HH. As noted by another participant:

> "Having energy was part of my imihigo. I have started the installation with on-grid system. However, the cost related to it was high. Then, I adopted off-grid system because I can pay little by little which is affordable." (Male participant, PPW9, Musanze)

Affordability was seen by the above study participant as the ability to pay for electricity in smaller instalments, both in terms of repaying the system price over time (rather than in full up front), and because of the PAYG model which allows micro-payments, whether on a daily, weekly or monthly basis, depending on customer's preference. Additionally, the price was compared to a grid connection which was initiated at the house but was found to be expensive.

5.2.6 SSHS as energy access solution: temporary or permanent?

Nearly 70% of survey respondents declared that the SSHS was a permanent energy access solution for them. Just under 20% said it was a temporary one. The full breakdown in show in Figure 5.43.

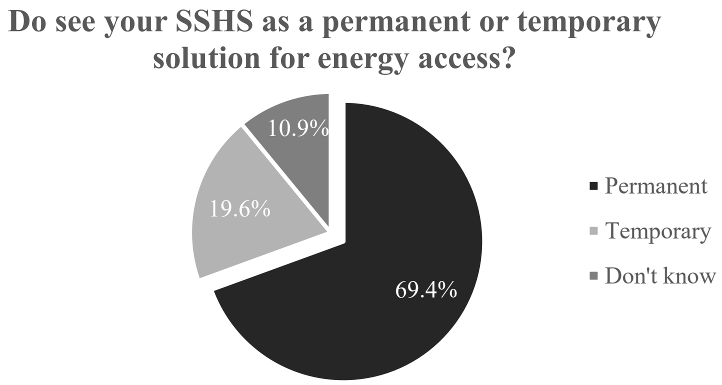


Figure 5.43. Perceptions of a SSHSs as a permanent or temporary solution for energy access (n=265).

Among those who said they considered it a permanent energy access solution in their HHs, 28.3% fell under the LLP poverty group, 40.8% under the ILP, and 31% under the HLP one. Among those for whom it was a temporary solution, the numbers were reversed between LLP and HLP, with 34.6% from the LLP group, 48.1% from the ILP one, and 17.3% from the HLP group. Although there was no significant association between the view on whether it was a permanent or temporary energy access solution and poverty levels ($x2=4.143$, $DF=4$, $p>.05$), HLP group customers were much less likely to see it as a temporary solution as compared to LLP and ILP group ones.

Looking at gender split, 71.2% of those who responded ‘permanent’ were men and 28.8% were women. However, looking at within gender (respondent) differences, more women thought it was a permanent solution than men (74.6% as opposed to 67.5% among men). In line with that, a lower proportion of female respondents perceived it as a temporary energy access option (15.5% of all female respondents compared to 21.1% of all male respondents).

Testing data for whether the likelihood of getting connected to the grid in the next 6 months (at the time of data collection) had an impact on whether the SSHS adopters thought of their systems as permanent or temporary energy access solutions for their HHs showed no significant effect (x2=4.462, DF=6, p>.05). 71.4% of those who said they were not likely to get connected to the grid in the next 6 months saw it as a permanent solution in comparison with 16.7% who saw it as a temporary one. Among those who declared that it was likely they would get connected to the grid in the next 6 months, 65.6% said they considered the SSHS as a permanent energy access solution vs 25.6% who said they saw it as a temporary one. 60% of those already grid-connected also saw SSHS as a permanent energy access solution. The below Figure 5.44 demonstrates the breakdown of responses.

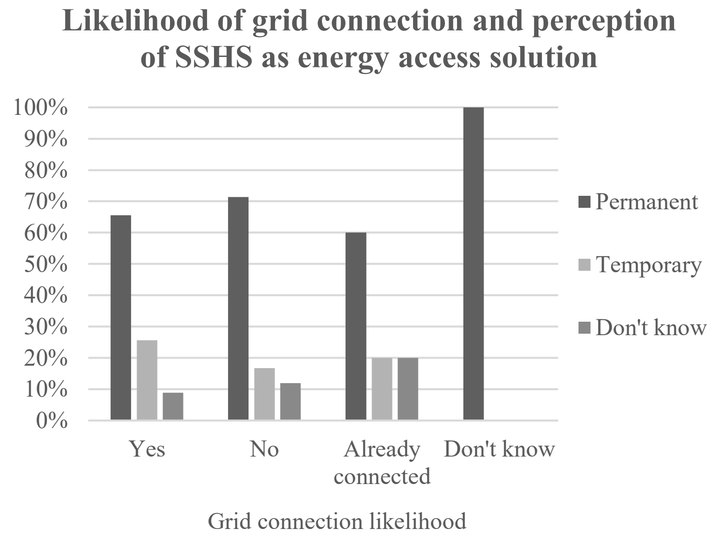


Figure 5.44. Perception of a SSHS as a permanent or temporary solution for energy access by likelihood of grid connection in the next 6-12 months ($\boldsymbol{n_{yes}}$=90, $\boldsymbol{n_{no}}$=166, $\boldsymbol{n_{alreadyconnected}}$=7, $\boldsymbol{n_{dontknow}}$=2).

Following on from the grid connection likelihood (in the next 6 months at the time of data collection), survey participants were also asked, much further in the survey (i.e. after numerous other questions) whether they would like to, eventually, get connected to the grid network. 48.7% said yes vs 45.3% who said no. 3.4% said ‘maybe’ whereas 2.6% were already connected to the grid. This aspiration to get grid connected and the perceptions of SSHS as a permanent or temporary energy access solution were cross-tabulated and the results are shown below (Figure 5.45).

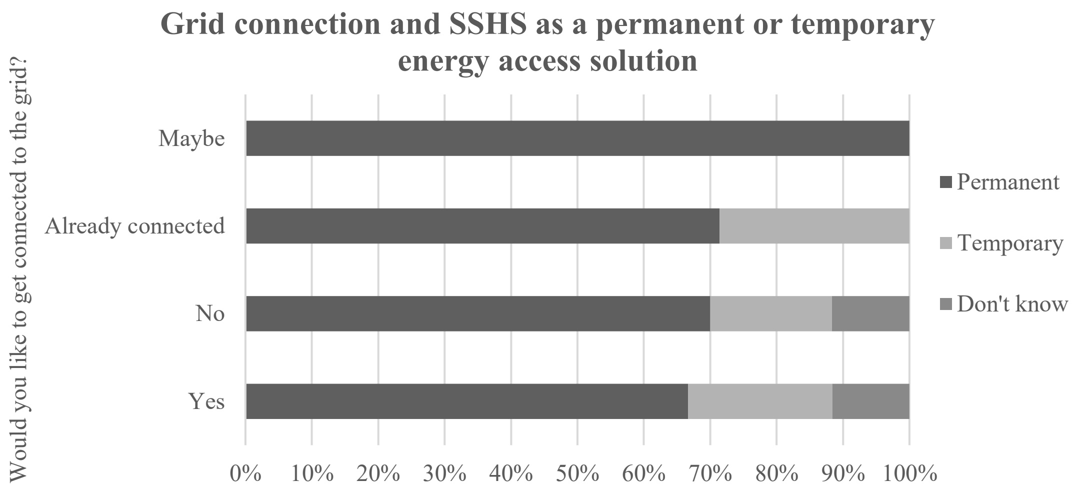


Figure 5.45. Perceptions of a SSHS as a permanent or temporary solution for energy access by aspirations for grid connection in the future ($\boldsymbol{n_{yes}}$=129, $\boldsymbol{n_{no}}$=120, $\boldsymbol{n_{alreadyconnected}}$=7, $\boldsymbol{n_{maybe}}$=9).

Even among those who would like to get connected to the grid network (if and when it becomes available in their area), 66.7% of respondents said they considered their SSHS as a permanent energy access solution. 70% of respondents among those who said they would not want to get grid-connected also saw their system as a permanent energy access option. 71.4% of those who were already connected said they, too, saw their SSHS as a permanent solution for accessing energy in their HH, which points towards the grid and off-grid solar systems as complementary rather than mutually exclusive energy access solutions.

During FG discussions, participants expressed their views on the comparison between the grid and off-grid options, and their preferences along with the willingness (or aspiration) to eventually get connected to the grid network.

One participant in FG1(1) stated:

> "We would like to stay with BBOXX if they reduce the price because it is safe, and if I won't pay more after paying the three years I owe them [referring to the ESF]." (Male, Nyarubuye)

In FG1(2), majority of participants said they would not like grid electricity, however, a couple of them added that they would like to switch to the grid if BBOXX did not increase the number of lights that come with their systems. Sentiments expressed in

FG1(3) were somewhat opposite, with all participants showing strong preference for switching to the grid when it becomes available, unless the price of the SSHS was reduced to match their capacity. Three participants in Gakoro (FG1(5)) also shared a reflection on the grid vs off-grid decisions they have pondered:

> "I have a grid pole at my home, if I do not get better services I shall join. However, I would not run for the grid because I know it can cause the electrical shock especially for my children." (Male participant, FG1(5), Gakoro)

> I have been refused to get a TV, and my children always run to the [community] centre to watch movies there and if I could have the TV at home that would not happen... Therefore, I will join the grid as soon as the installation is over." (Female participant, FG1(5), Gakoro, has previously been refused a TV for her system)

> "I am old, there is no need to join the grid... I will finish to pay for my system and enjoy my system afterwards." (Female participant, FG1(5), Gakoro, elderly)

Perceptions of the grid are driven by a number of factors: safety (grid unsafe vs off-grid safe), services and needs (grid offers more/can cover more needs vs off-grid is limited/does not cover all needs), affordability (conflicting perceptions: some believe off-grid is cheaper vs others see grid as cheaper), and other personal factors (e.g. age-elderly see off-grid as sufficient vs younger customers would like to get connected to the grid). Aspirations for grid connections and the reasons behind them will be further discussed in section 5.3.

5.2.7 Community perceptions of solar energy and SHSs

When asked about community perceptions of SHSs, survey respondents provided a diverse range of answers, encompassing all different attitudes towards them. The 10 top responses are shown in Figure 5.46 below. Nearly 70% of respondents said members of their communities liked off-grid solar systems, however, 62.2% also said that they found the prices of the systems too high. 20% of all respondents reported that many community members had already adopted SHSs in their HHs (the top 4 shop areas were: Vunga with 40% of all customers belonging to that shop reporting so, Kirambo with 22.2%, and Gasiza and Kidaho with 20% and 18.8% respectively).

However, respondents who belonged to the Kirambo shop area were also the ones who made up most of those reporting that many of the community members had been repossessed (after adopting a SHS), meaning they used to have a SHS but no longer do now (at the time of data collection). Among the 4.6% of all survey respondents who declared it, Kirambo shop customers made up 66.7%. Each of the other four shops where repossessions were reported as one of the community perceptions of SHSs had one respondent declaring it.

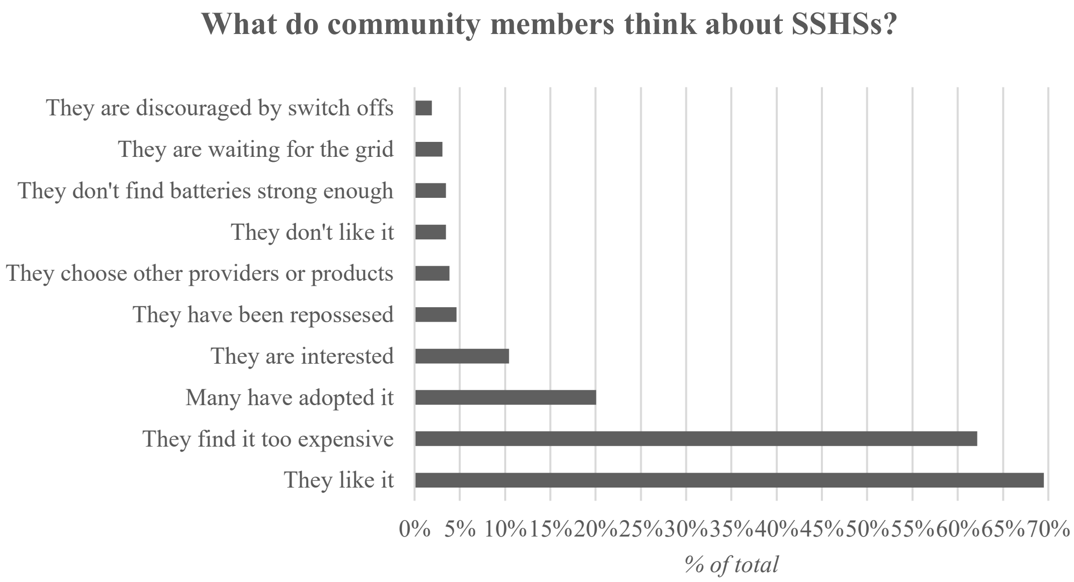


Figure 5.46. Community perceptions of (S)SHSs as reported by survey respondents (multiple response, n=265).

Other responses included: discouragement by switch offs (because of late payment), being already grid-connected, finding system batteries as not strong enough, and concern about the quality of the system post the 3-year repayment period (also signifying lack of awareness of the ESF which ensures warranty services after the 3 years). A male participant of FG1(5) shared his comments on how the community perceive SHSs:

> "The community think we are wasting money because the grid is here. Our counterparts from Mobisol always mock us especially when they cut us off asking why we got that kind of system that can't even understand you might not get money. Others are jealous and think we won't pay [off] all the money, and so forth. Others still think BBOXX is expensive than other [generic] solar systems we get from Uganda starting from RWF70000, lighting many lamps and for a long time." (Male participant, FG1(5), Gakoro)

The increasing number of generic SHSs, which the above quote refers to, has been seen across the country but in particular in the North, in places close to the Ugandan border (as mentioned in section 5.2.1). Customers in Kidaho, which is a town located only a few kilometres from the border, who participated in the survey mentioned the availability of SHSs from Uganda being sold in shops on a cash basis (no financing, no warranty or a short warranty period). They were sceptical of those systems themselves, worried that if they bought one there would be nobody to report to in case of any problems. Some community members shared those worries, however, others, even if they did too, would still purchase them as they are cheaper than SHSs offered by BBOXX or other providers in the region operating on a similar basis as BBOXX (i.e. no off-the-shelf purchase). One survey participant said:

> "Most are going to market sellers to buy solar system. Even though they are small with a small life span, they are willing to go for them." (Male respondent, S2, Byangabo)

Another one, when talking about how the community perceive solar systems, and referring to how they perceive those provided by BBOXX, explained that:

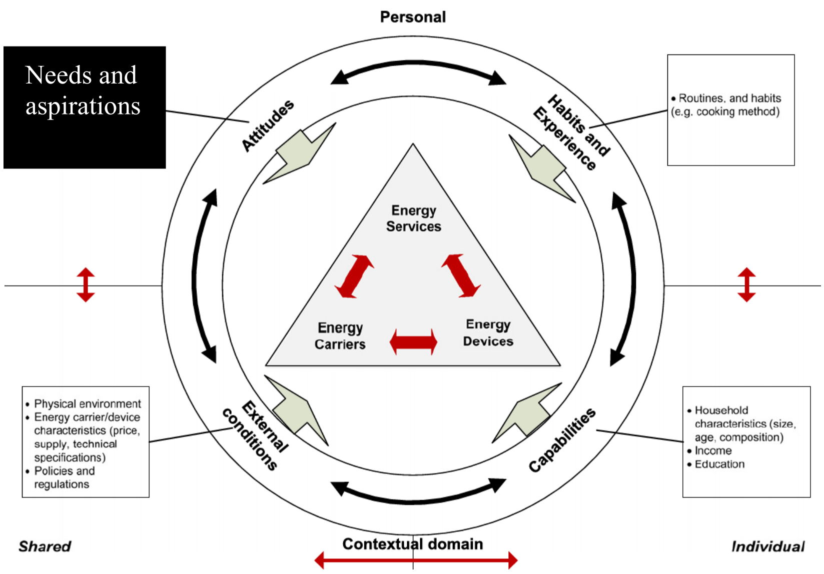
> "They [people] don't like to be oppressed or frightened if you don't pay they will remove the solar panel. Most of them are buying solar panel from Uganda, cheap and no more payment." (Female respondent, S2, Kidaho)

Another sentiment regarding community perceptions of SHSs shared by a male survey respondent in Mahoko referred to the interplay between the planned grid connections and choices to adopt an off-grid solar system:

> "More people here would have subscribed to BBOXX if you had come first, there is a cooperative that put together most of the people who wanted electricity and charged them the fees to bring the electricity in the village, but now they are late, I don't know, but the electric poles are just outside there. But they are jealous that I have light before them, and I pay less every month, while they did pay a lot at once to get it." (Male respondent, S2, Mahoko)

Those who are interested in getting a grid connection are required to pay a connection fee (at least $60) to secure the connection. However, often it takes a long time between when the connection fee is paid, and the grid connection is provided, which leaves people in a challenging position of having already paid but not having the service available yet. Even though customers adopting SHSs (whether BBOXX's or those of other providers) rarely get their systems installed on the same day as they subscribe by paying the down payment, they usually wait up to a few weeks (an estimate for how long the wait might be is given at the time of subscription) whereas in the case of the grid it can take up to a few years. The more immediate availability of SHSs is what the above respondent referred to by comparing those who are still waiting for the grid and himself who gets the benefits of having electricity in his house without the long wait.

5.3 Needs and aspirations



Questions around energy needs encompassed all three core areas of the three-dimensional energy profile: energy devices, energy carriers and energy services. Survey, FGs and PPWs participants were asked about the energy needs at the HH level and whether or not they were satisfied by the SSHS. Basic energy needs have been teased out from the FG discussions where participants also had the opportunity to express what needs remain unmet, as well as what future aspirations they have in terms of energy access in their homes. An *aspiration* is typically defined as a hope or an ambition of achieving something, whereas a *need* is something that is required, a necessity. The former is usually considered as not something critical for survival (or well-being), as opposed to the latter which is urgently important to ensure well-being. The concept of *basic needs* has been put forward as a measurement of the poverty line globally, allowing for the establishment of the very minimum resources required for long-term well-being, particularly in terms of human physical well-being[39]. The *basic needs approach*, as argued by Streeten (1979: 136), has an objective of "[..] provid[ing] opportunities for the full development of an individual. It focuses on mobilising particular resources for particular groups, identified as deficient in these resources." In this study, human needs and aspirations are investigated through the lens of energy access, focusing on what the basic energy needs are among rural households in Rwanda, and what needs beyond them can be identified, along with future aspirations of the HHs regarding energy access, particularly concerning energy services and energy devices. While cooking, as a service which falls under energy access, is considered among top household expense priorities, which are examined in section 5.3.5, it is not explicitly included in this study as SSHSs currently do not support it. However, it is referred to throughout this study and its importance is recognised, as is the fact that it is one of the pressing energy needs which is not supported by the off-grid solar solutions.

5.3.1 Is SSHS enough? Basic energy needs

Lighting followed by mobile phone charging are the most basic needs which respondents in all FGs listed out as the most important to them and their families. Light, in particular, is transformative and even though all participants used to use other lighting sources prior to purchasing a SSHS, having a clean, reliable source of light was one of the key motivations for adopting a solar system (as discussed earlier in section 4.3.2). As recent years have seen a wide spread of the mobile technology and services, the reliance on mobile phones has become ubiquitous. As a result, mobile phone services, and especially mobile phone charging services, have become pivotal for urban and rural dwellers alike. All participants of this study owned at least one mobile phone in the HH, and often more. The ability to charge one's phone at home instead of having to use charging stations (often requiring travel for long distances,

[39] The basic needs strategy for development stemmed out from the work of the International Labour Organisation World Employment Programme (WEP) in the 1970s, but the concept of basic needs was first proposed in the psychology literature in 1940s.

and always provided at a charge) was considered to be another key reason for the adoption of a SSHS.

When asked about whether a SSHS meets all their energy needs, the results were as follows (Figure 5.47):

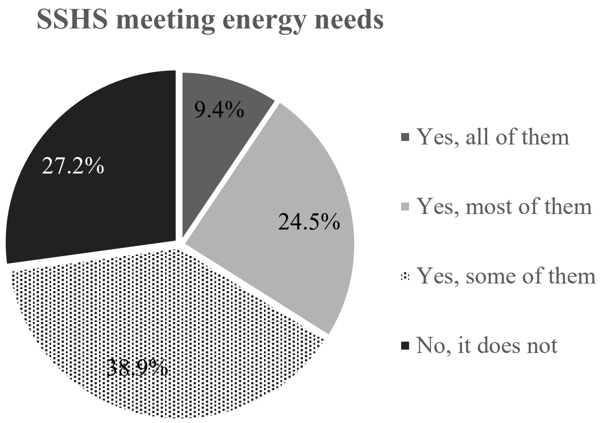


Figure 5.47. Survey participants' perceptions on whether a SSHS meets their energy needs (n=265).

For fewer than 10% of the respondents the system met all their energy needs. Among them, all were either very satisfied or satisfied with the amount of energy provided by the system and all of them mentioned having light as the reason for choosing 'all of them' as their response. Phone charging, listening to the radio, watching TV and being able to generate income with the use of the system were mentioned by 5 respondents in that group, respectively.

Those for whom most and some needs were met by their SSHSs the most pressing outstanding need was to get more lights, followed by more USB ports for phone charging. Other needs consisted of well-functioning existing appliances (e.g. lights, radios and TVs), and the ability to get other appliances, such as radios and TVs (for those who did not already have them). These can be considered the additional basic needs which stem either from not having enough of the already owned appliances (lights and USB ports/cables for phone charging) or having malfunctioning, already owned, appliances. The need of being able to plug in appliances other than just the ones provided by BBOXX could be considered either basic (if the appliances are already owned and cannot be powered by the system), or aspirational (if the appliances are not yet owned but are desired). Having the ability to use the system for income generating purposes was also regarded as one of the unmet needs, which is an aspiration discussed in section 5.3.3. On the energy carrier aspect, a stronger battery which would translate into longer hours of system use was mentioned by 21% of respondents among the 63.4% whose most and some needs were met. These two aspects were present among justifications for why the system does or does not meet the energy needs.

Based on what the study participants reported as their basic appliance needs and aspirations for additional appliances, the hierarchy of appliances can be presented as the following:

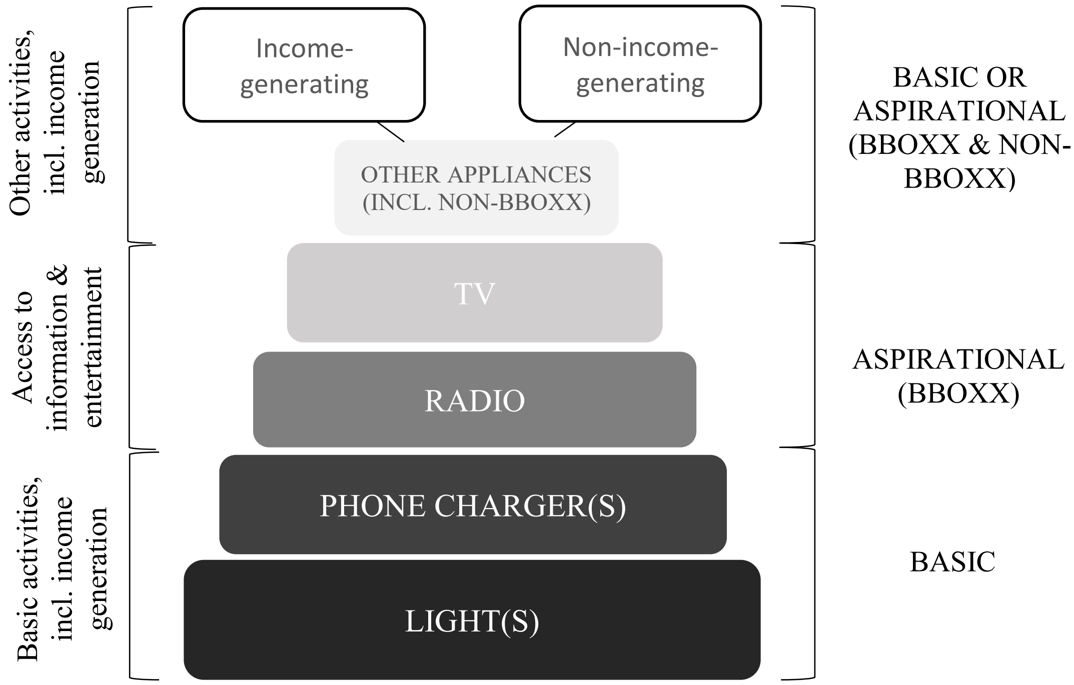


Figure 5.48. Hierarchy of appliances according to expressed needs and aspirations for additional appliances among study participants.

A significant relationship was observed between the level of satisfaction with the amount of energy provided by the SSHS and whether energy needs were met ($x2=41.694$, $DF=12$, $p=.000$) (Figure 5.49):

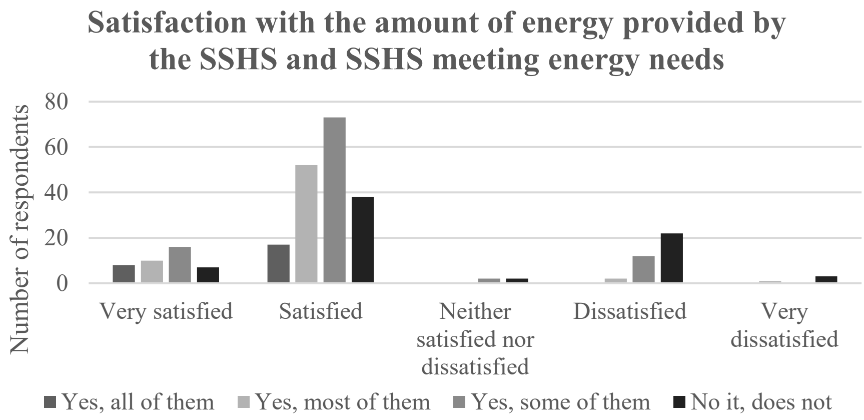


Figure 5.49. Survey respondents' satisfaction with the amount of energy provided by the system by energy needs being met by a SSHS.

Another significant relationship was detected between the system meeting energy needs and gender (x2=10.135, DF=3, p<.05), where fewer needs were met for women and more women felt their needs were not met than men. Results are demonstrated in Figure 5.50 below:

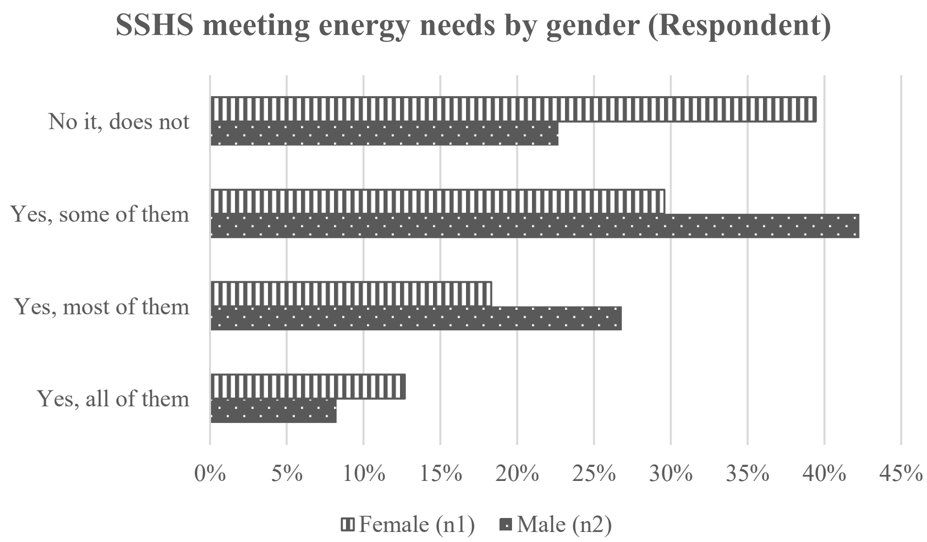


Figure 5.50. System meeting energy needs by gender (respondent) (n1=71, n2=194).

A considerably higher proportion of women than men felt that the system was not meeting their needs (39.4% vs 22.7%), which is a result of women using the systems more and having more in-HH energy needs than men. On the other hand, 12.7% of all women responded that all their energy needs were being met by the system vs 8.2% of all men. However, these numbers are relatively small (9 and 16, respectively, as mentioned earlier in this section).

Taking energy access as a proxy and cross-tabulating the responses on whether the SSHS was seen as a permanent or temporary energy access solution with the responses on whether the SSHS meets the energy needs of the HH showed that even when the respondents do not feel the system meets their energy needs, majority of them still perceive it as a permanent energy access solution (Figure 5.51).

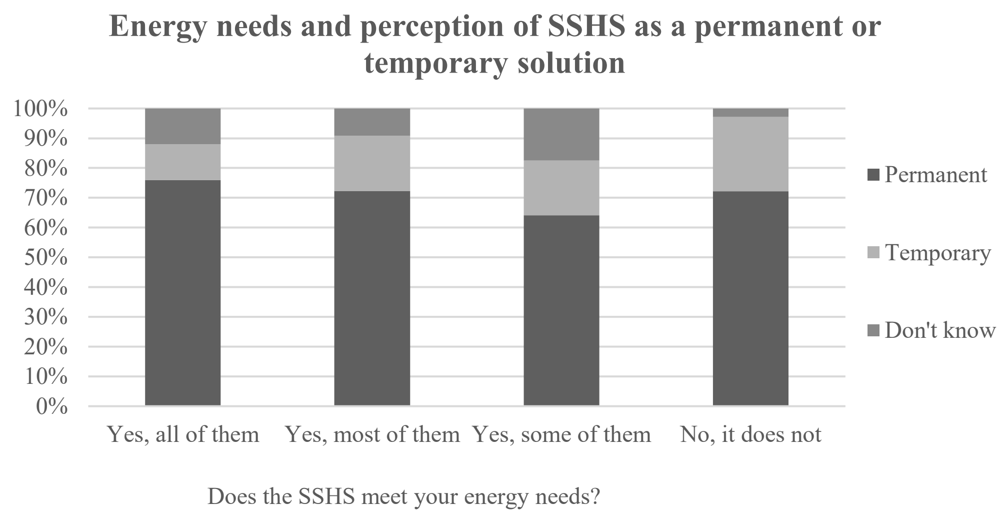


Figure 5.51. Perceptions of a SSHS as a permanent or temporary energy access solution by energy needs (n_{all}=25, n_{most}=65, n_{some}=103, n_{no}=72).

Those who said the system was only meeting some of their energy access needs had the lowest proportion of respondents who considered their SSHS as a permanent solution for accessing energy (at 64.1% vs 76% of those whose all needs were met and 72.3% of those whose most needs were met), with 72.2% of those whose needs were not met seeing it as a permanent energy access solution. This shows that even those users whose energy access needs are not currently met (by their SSHSs) are still interested in keeping the systems and either upgrading them or complementing (with the grid or other solutions) in order to have more or all of their needs covered

5.3.2 Next/future appliances

Separate from justifying why energy needs were or were not being met by the SSHS (as a follow up to the question on whether all, most, some need or needs not being met question), survey respondents were also asked about what the next appliance(s) would be that they would like to have. A multiple choice was allowed, and the results are shown in Figure 5.52 below.

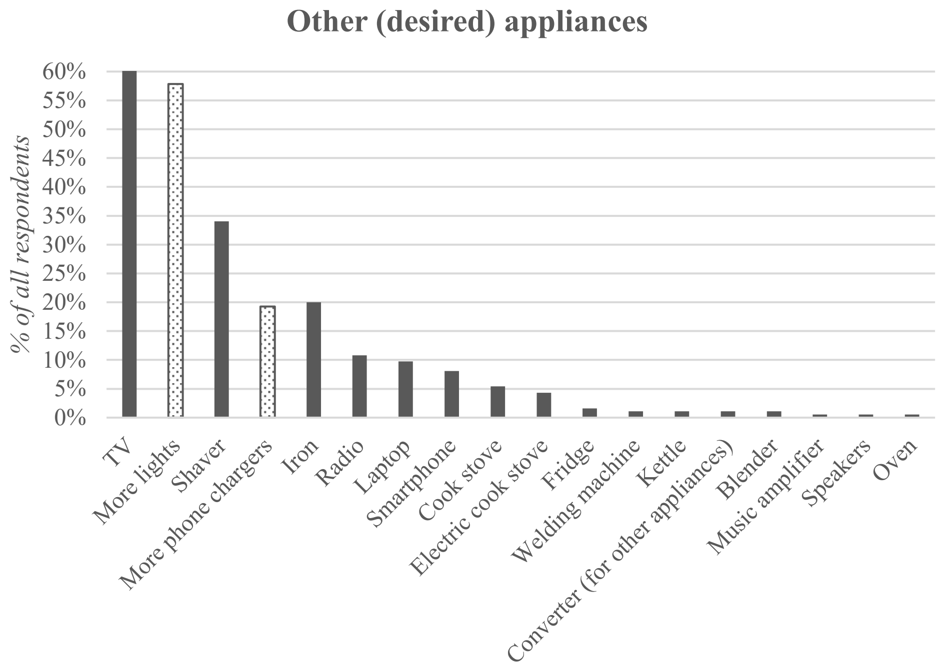


Figure 5.52. Additional appliances desired by survey respondents (multiple response, n=265, total responses=488). Dotted pattern marks appliances which all participants have included with their system.

Among the appliances that respondents listed out as the next/future ones they would like to have, lights are the ones which all of them already have (the number of light bulbs varying across the sample). However, in line with what they reported earlier as an elaboration to the energy needs being met question, a high number of SSHS adopters would like to have more lights than the number they currently have. Using one of the lights as a security light, placed above the front door, is very common among SSHS users and if only two light bulbs are available, there is only one that can be used indoors. Even those adopters who have system with a higher number of light bulbs often felt that they needed more so that they could light up their entire house. One respondent who has switched from a grid network to a SSHS also said:

> "2 bulb lamps are also a problem to someone who used to have electricity in the whole house." (Female respondent, S3, Musanze)

Those who expressed wanting more phone chargers, similarly as in the case of lights, already had phone charging available to them but wanted to have more of them to be able to charge more phones.

Shavers were needed for two reasons: either to open a barbershop or for use in the family (thus eliminating the need to use a barber service elsewhere, which comes with an additional time and financial requirement). TVs and radios were mostly wanted for access to news and entertainment (e.g. sports matches among men), as well as to keep the children at home instead of them having to go outside to watch TV. Irons were predominantly desired by women respondents for own use at home. Those women who have irons often use those which require charcoal to heat, which tends to be costly and inefficient. Some women also saw irons as an appliance which could be used for income generation (providing ironing services). Laptops were mostly wanted for work purposes and for accessing the internet, similarly as smartphones. Those respondents who mentioned transformers as other appliances they would like said they were needed to plug in appliances other than just those provided by BBOXX. For those who considered the inability to plug in other appliances as a challenge, it was the higher battery capacity and a higher number of USB ports and/or transformers which they mentioned were necessary to address it. Despite the guidelines from the provider being that no other appliances other than those which are provided and come with the system or can be added to the set of those included in the original package should be plugged into the system, those respondents were still interested in doing so. A cook stove (whether electric or other) was the appliance mentioned as needed for improved cooking (including smoke reduction and faster cooking), as well as for the reduction of cooking fuel expenditure, as put by one survey respondent:

> "If I could get an electric stove it would help much because firewood is consuming much of our income." (Male respondent, S3, Byangabo)

Another male respondent reported that he would like a cook stove for his family because "[…] firewood is very stressful to find" (male respondent, S2, Kabaya).

Figure 5.53. A word cloud showing the 100 most frequent words used by survey participants to explain why they would like the additional appliances of their choice**.**

Among FG1s participants, in each of the five FGs majority of participants said they would like to have a TV as their next appliance. In three out of five FGs more lights were also expressed as a critical need that remains unmet. Other appliances or energy services which were desired among participants (in order of frequency of being mentioned) were: shavers, irons, cook stoves and other (non-BBOXX) appliances which could be plugged in to the system (unspecified, mentioned as an expressed need or willingness for being able to plug in other appliances rather than just those provided by BBOXX).

7 out of the 20 PPW participating HHs had a TV and 10 out of the 13 who did not, said they would like to get a TV as their next appliance. 4 said a torch (a portable light) would be the next appliance of choice, and the same number expressed the need for more lights. Shavers and kettles were also among the appliances HH members would like to own, with each one picked by 3 HHs. Additionally, 3 participants said a stronger battery that could support more appliances would be desirable so that they can also plug in other appliances, other than the ones they can get from the provider.

The expressed aspirations for more/different appliances were relatively consistent across all study participants, with some appliances, such as TVs, more lights, more charging ports/cables for phone charging, shavers etc. being generally very desirable. However, despite the great majority expressing aspirations for expanding the range of their appliances which they can use with the SSHS, and only a small proportion saying they were satisfied with what they already had, as few as one survey participant added an extra appliance to his SSHS package between August/September 2016 and September 2017, when records of upgrades among survey participants were checked against their original systems and appliance sets from the time of data collection (i.e. August/September 2016). A follow up with all the survey and FGs participants who were still actively using their systems in September 2017 was not possible due to capacity and time constraints, however, the very low level of upgrades (or new/additional appliance acquisition) poses an important question on what the barriers to upgrades are and how they can be addressed, given the high expressed aspiration and willingness of study participants to have more of the already owned appliances (e.g. lights) and other, additional appliances for use with their SSHSs.

5.3.3 Aspirations for income generation/productive uses

Aspirations for income generation with the use of a SSHS were tested by asking study participants if they would be interested in using their systems for productive uses or income generation (used interchangeably and signifying any use of the SSHS for generating income, whether directly (e.g. phone charging) or indirectly (e.g. use of lights in a business place). Among survey respondents, 12.1% were already using their system for income-generating activities (Figure 5.54). The two appliances used were lights and phone chargers.

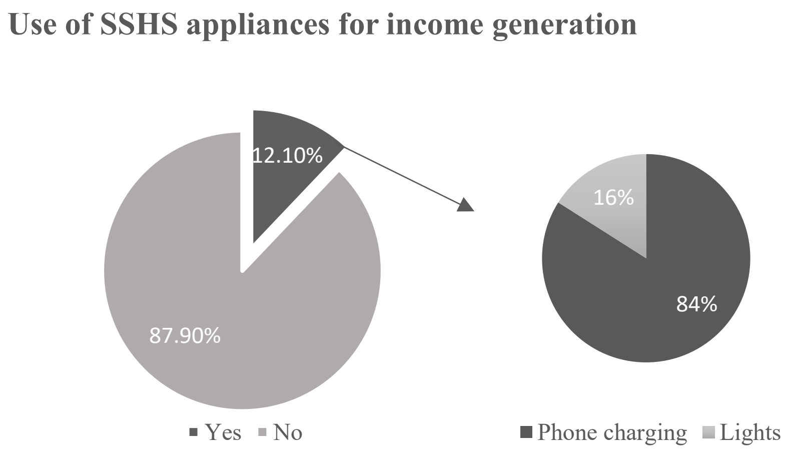


Figure 5.54. Percentage of survey respondents who do and do not use their SSHS for income generation (on the left) (n=265) and appliances used to that end among those who do (on the right).

Men made up 90.6% of those who were using their systems for income generation, whereas women represented 9.4% of that group- nearly ten times fewer than men. The highest proportion (46.9%) belonged to the LLP group, with 25% who fell under ILP and 28.1% in the HLP, pointing to those in the LLP group as more likely to use their systems for income generation (x2=6.633, DF=2, p<.05).

Among the nearly 88% of respondents who were not using their systems for productive uses at the time of data collection, many reported wanting to do so in the future (Figure 5.55):

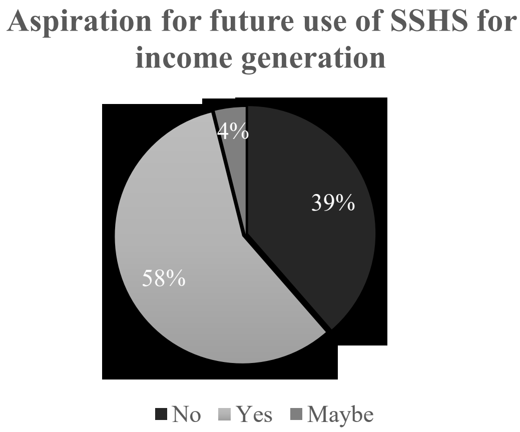


Figure 5.55. Aspiration for future use of a SSHS for income generation among survey respondents who do not yet use it for income-generating activities (n=233).

Willingness to use the system for productive or income-generating activities was higher among women than men (x2=5.629, DF=1, p<.05), with more men already using it for income generation than women (Figure 5.56).

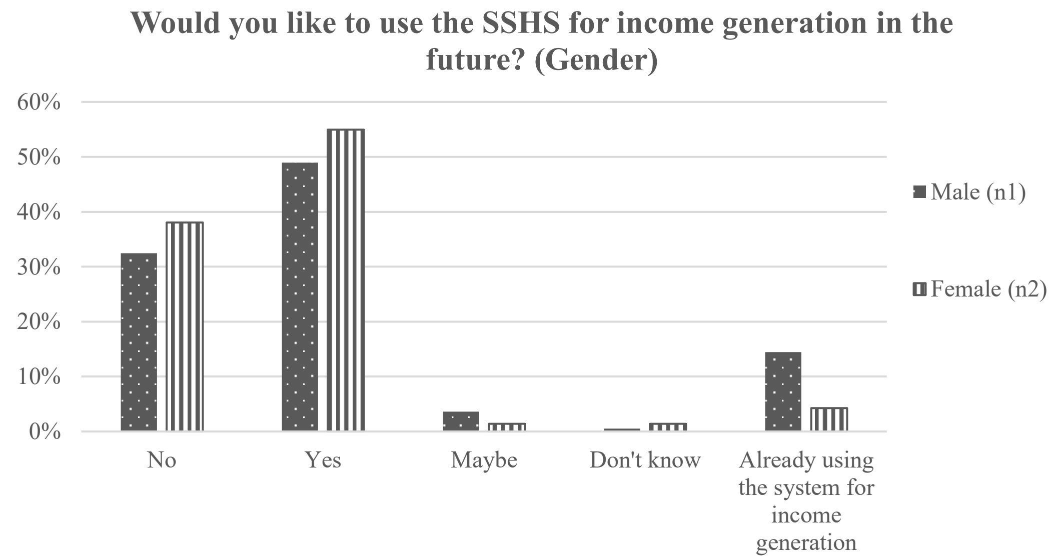


Figure 5.56. Aspiration for future use of the system for income generation by gender (respondent) (n1=194, n2=71).

As was discussed earlier, Group 3 customers, on average, use their systems for income generation more than those in the other two Groups. Aspirations for using it for such activities in the future among those who do not currently generate income through the SSHS is equal among the three Groups, as indicated in Figure 5.57 below:

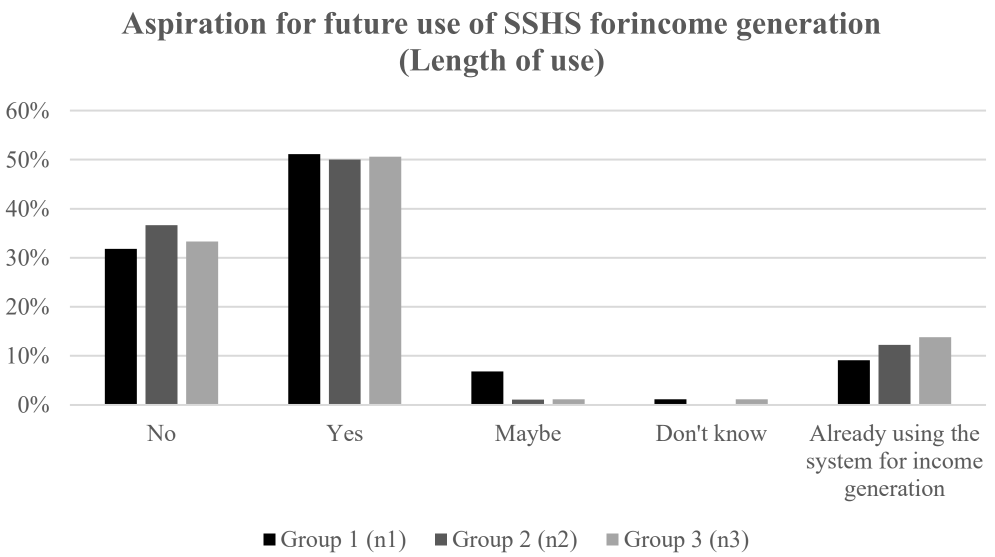


Figure 5.57. Aspiration for future use of the system for income generation by length of use (n1=88, n2=90, n3=87).

Among those who said they would like to (or 'maybe' like to) use their system for income generation in the future, the following appliances were considered potentially the most useful for doing so (Figure 5.58):

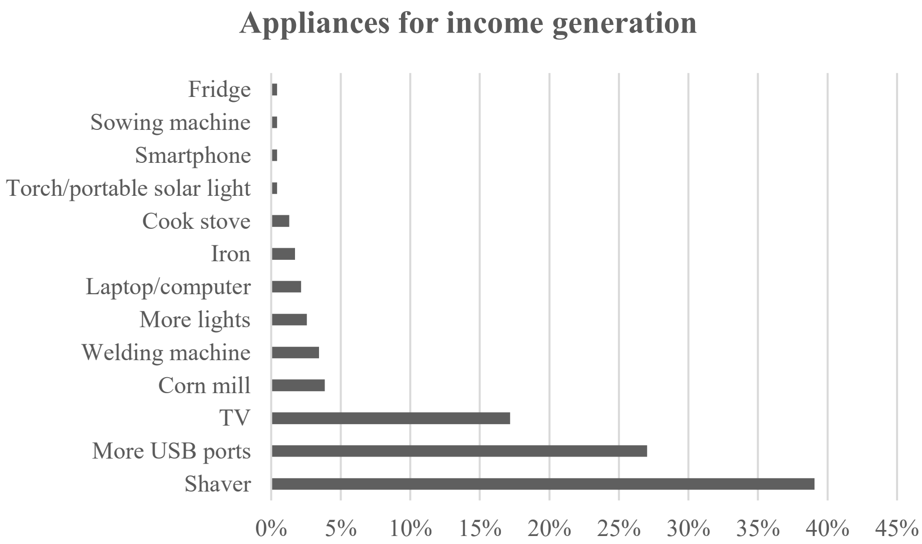


Figure 5.58. Appliances which would enable income generation as expressed by survey respondents who do not currently use their systems to that end (n=233).

The highest number of responses among both men and women was a shaver (followed by more USB ports and a TV for both genders as well), with the intention of opening a barber shop. A male FG1(3) participant, who also mentioned a shaver would be his next appliance that he would like to get, said:

> "If I could get a shaver, I would like to open a barber shop. I could also shave my kids." (Male participant, FG1(3), Cyuve)

Another participant of the same FG1(3) in Cyuve spoke about phone charging ports:

> "I would like to have more USB ports as people who come to charge their phones pay us money." (Male participant, FG1(3), Cyuve)

However, phone charging, even if offered to others outside of the HH, is not always a paid service. As expressed by one FG1(1) participant:

> "We do not plan for [use for income generation] because our systems are only capable for charging and it is not our culture to charge your neighbour for such a simple service." (Male participant, FG1(1), Nyarubuye)

Some SSHS adopters do not hesitate to use their systems to charge a fee for mobile phone charging and that way complement their income, as was also the case of the head of household who participated in PPW17, who channelled the profit generated from charging phones towards his monthly system payments, that way making the system work for itself. Yet others do not charge anything as they believe in the culture of sharing and exchanging favours: today it might be them helping a friend or a neighbour with a phone charging favour, but tomorrow they might need help themselves and the hope is that a favour will be reciprocated. This was explained by one of the participants of the FG in Gakoro:

> "When I finish to charge my phone, I can charge one for my neighbour's as well. It is in our culture to share and I feel it is needed to share the best I have got. I can't charge for the service because I might need a service from him/her later on... I also do not often charge [phones] for my friends because I have been told that the only number of phones I am allowed to charge a day are 2 max." (Female participant, FG1(5), Gakoro)

Others still expressed lack of ideas for how they could use the system for income generation as the reason for not using any appliances or wanting to use other appliances in the future to generate profit. One FG1(1) participant said that he had "[…] no idea what we can do."

System functioning and capacity were additionally seen as a potential obstacle to using it for activities that could generate income, even if there was interest in undertaking such activities, as was mentioned by the male FG1(4) participant in Nyarubuye and by others in their statements below:

> "We would like to do other business if the system was working properly." (Male participant, FG1(4), Nyagahinga)

> "We don't have any appliances used for productive uses because the energy is really not sufficient." (Female participant, FG1(5), Gakoro)

The sufficiency or capacity challenge (including, for example, too few USB ports or charging cables), and technical difficulties in cases where the system does not work as expected (whether due to limited capacity, faulty parts or other reasons) links to the aspiration of connecting to the grid in the future, which is discussed in the following section.

5.3.4 Aspirations for grid connection

Likelihood of getting connected to the grid in the near future is lower than the willingness to eventually get connected to the grid (Figure 5.59).

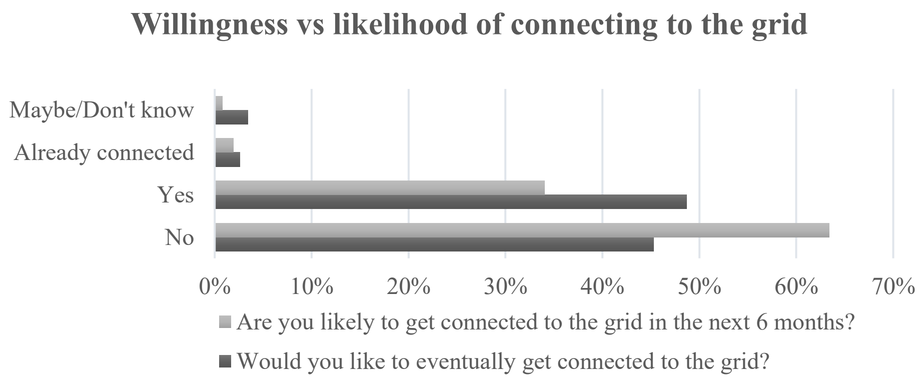


Figure 5.59. Willingness vs likelihood of connecting to the grid network among survey respondents (n=265).

7 out of the 265 survey respondents were connected to the grid at the time of data collection, as compared to 9 who had been connected prior to adopting a SSHS (2 have opted out from the grid altogether after installing the systems in their HH). A discrepancy was detected between two questions where respondents could report already having a grid connection, as is also noticeable in Figure 5.59 above. The difference of 2 respondents who reported already having a grid connection (5 and 7) results from additional 2 customers who have stopped using the grid although they have retained the connection (i.e. from the 9 who had connected before adopting a SSHS, 7 still have it and 5 still use it).

The lowest number of already grid-connected SSHS users came from the HLP group, with those in that group also representing the lowest percentage of those who said they would like to eventually get connected to the grid (among those who were not yet connected at the time of data collection). Figure 5.60 demonstrates the breakdown of the three representations of the three groups in the answers to the question on eventually getting connected to the grid network.

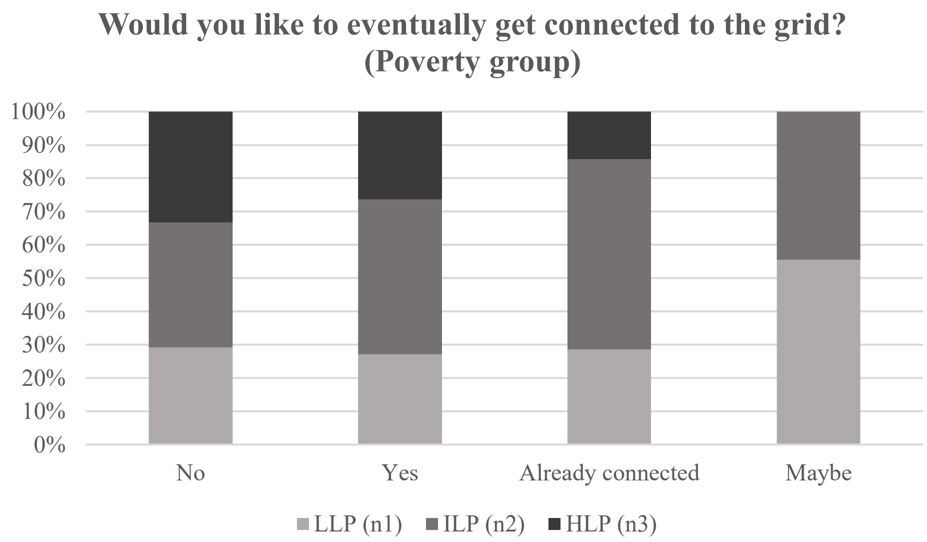


Figure 5.60. Willingness to connect to the grid network by poverty group n1=77, n2=113, n3=75).

Data showed no significant effect in the relationship between the aspiration for eventually getting connected to and the distance from the grid (x2=56.241, DF=78, p>.05; r=.747, p>.05). 50% of those who said they would not want to get connected to the grid network lived 20 minutes or less away from the grid (and constituted 22.6% of the total number of respondents). 48.8% of those who said they would like to get connected to the grid network lived 20 minutes or less away from the grid (and constituted 23.8% of the total number of respondents).

Reasons for either wanting or not wanting to connect among survey respondents (who were not already connected) were diverse: from aspiring to have all the energy needs met to seeing off-grid solar systems as safe and/or sufficient.

The main three reasons for wanting to eventually connect to the grid network were:

- The ability of the grid to meet all one’s needs (related to energy access) (particularly for respondents in Group 2);
- The ability to plug in other/more appliances (particularly for respondents in Group 2); and
- Grid electricity being [perceived as] cheaper.

The main three reasons for not wanting to connect were:

- SHS (used in the same way as SSHS) being enough/sufficient in meeting energy access needs;
- The inability to afford a grid connection (particularly for Groups 1 & 3); and
- No grid plans in the area in the near future.

For a detailed breakdown of responses, see Figure 5.61 below.

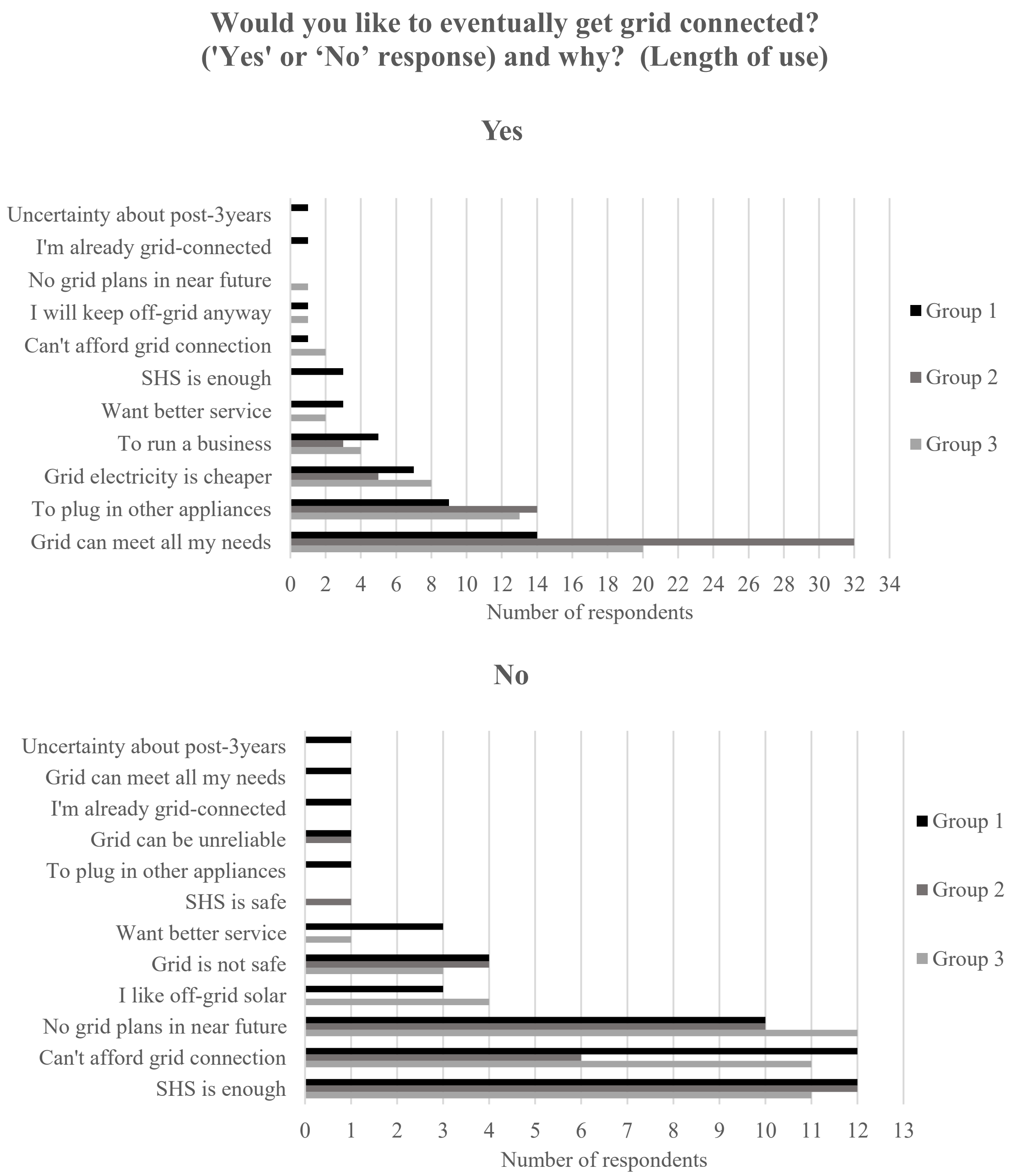


Figure 5.61. Willingness to connect to the grid network and reasons for both wanting and not wanting to do so by length of use.

The above reasons were also reflected in FGs discussions, where participants' perceptions and aspirations for the grid were divided in a similar manner to the responses of survey participants: for some, the SSHS was sufficient, whereas others felt it could not meet all their needs and they would therefore like to get a grid connection when it becomes available. This was expressed by several participants in FG1(3), with one of them saying:

> "I want to switch to the grid system as it is cheap, and it accommodates many products [appliances]." (Male participant, FG1(3), Cyuve)

Another one expressed hope for the SSHS to meet all the needs, and not having to switch to other systems:

> "The energy source will have improved. We are getting more options, and I hope we will have what we want. I wish they improve the system because I can't keep switching to new systems. It would be a huge loss of money." (Male participant, FG1(5), Gakoro)

Another one yet said:

> "I will stay with BBOXX if the reduce the price, otherwise I will opt for the grid." (Male participant, FG1(1), Nyarubuye)

One participant of FG1(2), on the other hand, said that he had switched from the grid to the solar system because of the unreliability of the grid and because he worried the children could get electrocuted, and that he would not like to switch back to the grid but that he would like to have more lights so that his needs are satisfied.

5.3.5 Household expense priorities

During FG1(1-5) and FG2(6-10), monthly priority expenses in the HH were discussed with the participants to gain understanding about how the resources are allocated and which needs are among the top ones. FG discussions revealed a set of priorities which HHs allocate their financial resources to (on a monthly basis), those included (in a random order): BBOXX SSHS[40] (post-adoption), SACCOs (Savings and Credit Cooperatives), food, school fees, water, cooking fuels, rent, other lighting sources (such as candles, kerosene etc.), and other expenses (unspecified in the survey). Survey respondents were asked to indicate their top three priorities from before they adopted the SSHS and now (Figure 5.62).

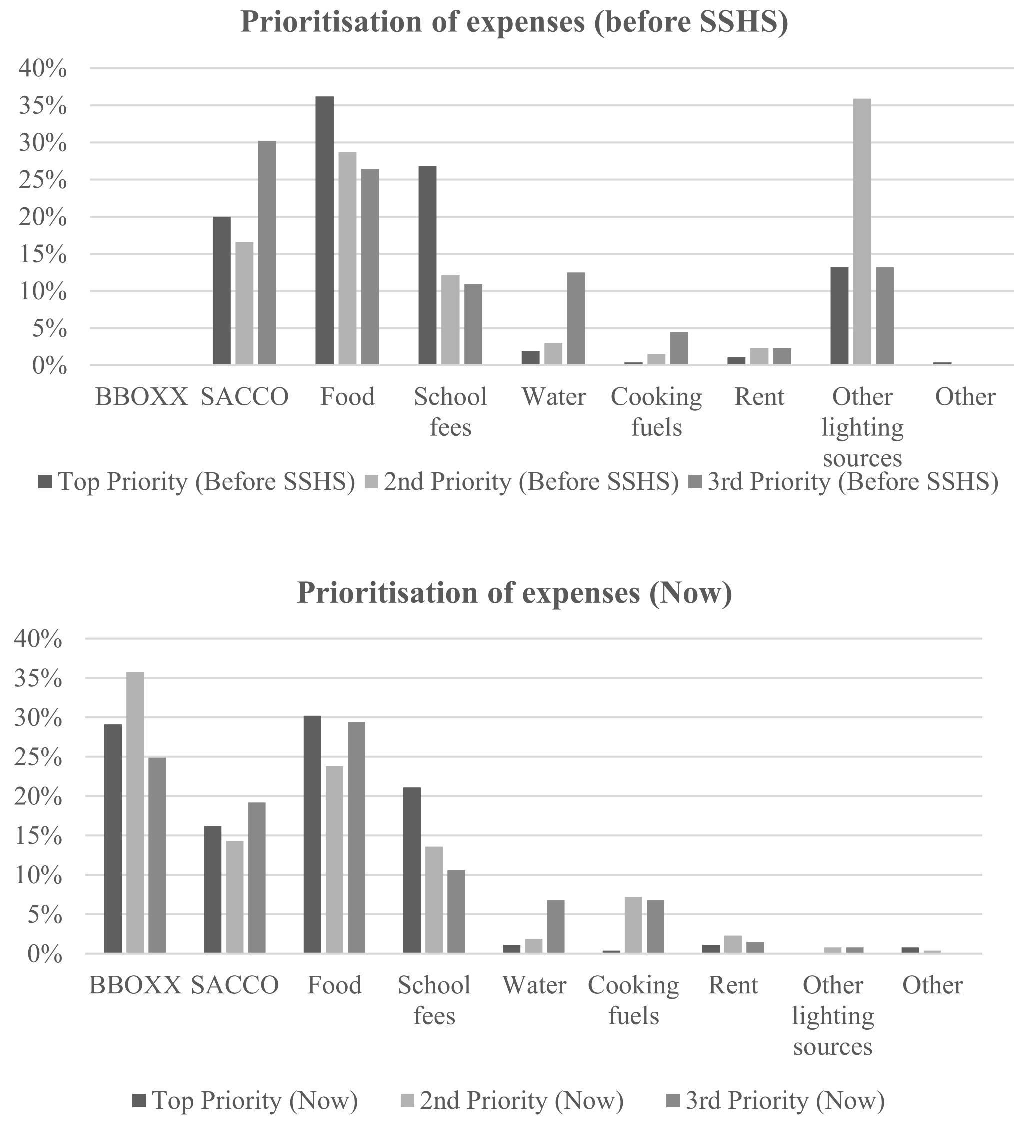


Figure 5.62. Expense prioritisation of survey respondents (demonstrated separately for before SSHS and now) (n=265).

[40] Respondents usually refer to the system as BBOXX (pronounced "BBOXXy") hence BBOXX in the set of priorities. It means BBOXX SSHS.

As demonstrated in the above figures, after adoption, a SSHS became top priority for 29.1% of respondents, second priority for 35.8% and third priority for 24.9% of respondents. Expenditure on other lighting sources has been replaced with that spent on a BBOXX system. Food remained the top overall priority, although it dropped from 36.3% to 30.2% of respondents. A significant drop is observed in other lighting sources which have gone from 13.2% as top priority, 35.9% as second priority and 13.2% as third priority before having the SSHS, to 0%, 0.8% and 0.8%, respectively for the three priorities now. A slight decrease can be seen in the prioritisation of SACCOs and a slight increase in the prioritisation of cooking fuels.

This exercise has shown that household do prioritise SSHSs among their regular expenditures, which validates access to energy as one of the top needs in rural HHs.

5.4 Impact

Gaining access to energy services, such as lighting, phone charging, radio, TV or others creates a number of impacts, including socio-economic ones and ones related to well-being and the everyday life, which can change as a result of having those services available in the HH. This section links to what has already been discussed in section 5.1, particularly section 5.1.3, and to the motivations, needs and aspirations of SSHS users (section 4.3.2 and section 5.3), who not only see access to energy as an enabler, but also experience it in a number of different ways.

Key impact points have been examined in relation to women and children, safety and security, savings of time and money, as well as re-scheduling of daily activities (or daily routines) and the extension of productive hours. There have also been negative impact points reported by the study participants which mainly related to the challenges associated with payments and the resulting system switch-offs.

Among survey participants, the following were the key ways in which having the system has affected, or impacted on, their lives (Figure 5.63):

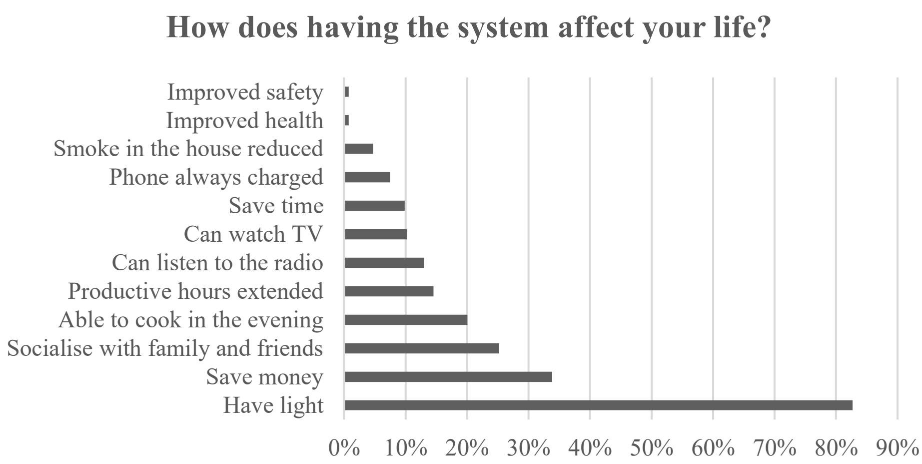


Figure 5.63. Ways in which having a SSHS affects life (multiple response) (n=265).

Negligible differences in the way the system has affected the lives of HH members across the three groups (1,2 & 3) (Figure 5.64) have been observed:

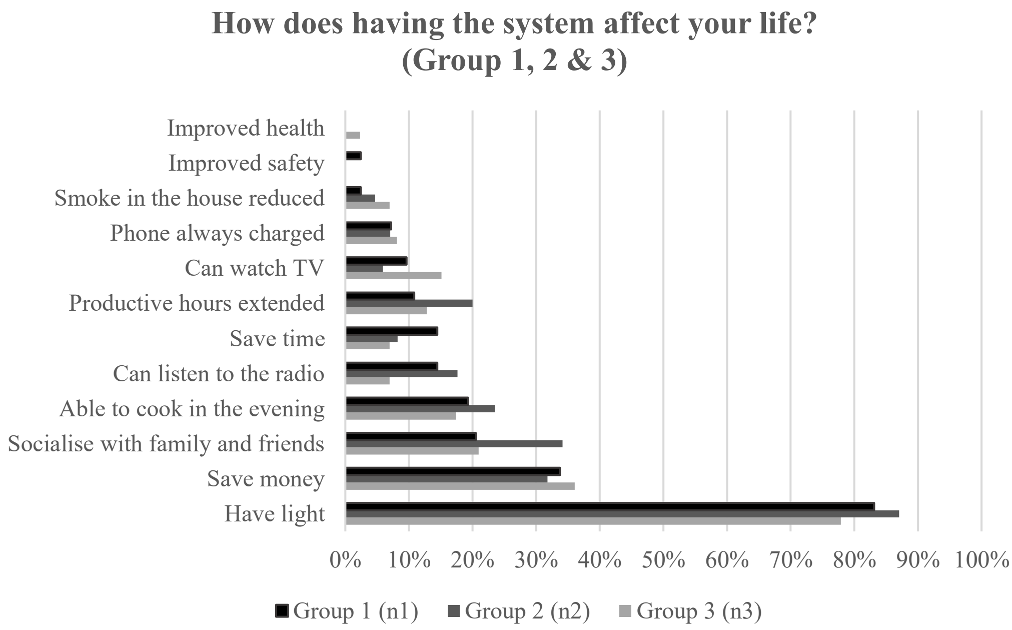


Figure 5.64. Ways in which having a SSHS affects life (multiple response) by length of use (n1=88, n2=90, n3=75).

Having a clean, bright and reliable source of light was the most appreciated and the most commonly mentioned point. Among those in-HH survey participants who agreed to have a photo taken with/of them or of their system, or anything else they chose to show in the photo (78 out of 97 HHs), lights were photographed 53 times. 100% of PPWs participants photographed lights as well. The ability to light up the house and to be in a bright environment in one's own house was frequently talked about both in FG discussions and PPWs. Light, which is the most basic service provided by SSHSs and one that everyone gets access to regardless of the system type they adopt, has been seen as the most impactful and transformative, and directly or indirectly linked to the other impact points which will be discussed in this section.

Selected photos from those taken of or by survey participants (who agreed to photos being taken) demonstrating the different ways in which participants wanted to show their lights and their importance (Figure 5.65): from providing a bright light (which could be observed even during the day), to lighting up spaces of common daily activities (e.g. women in the kitchen/storage/preparation areas) or being used as outdoor lights above or close to the house door.

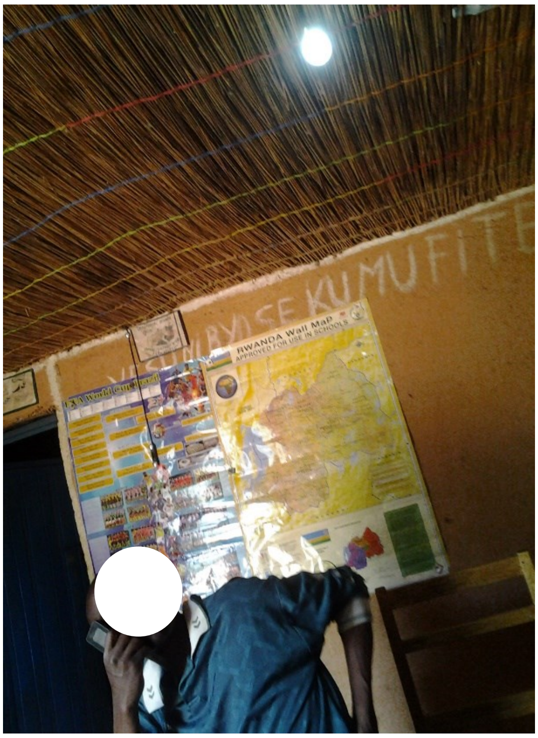

RWANDA Wall Map

Figure 5.65. Photos showing survey (S2) participants across the Northern and Western Province demonstrating the lights in their houses. Photo credit: M. Uwase.

Both in the case of survey and PPWs participants there was a noticeable sense of pride of having a modern source of lighting in their houses, which was perceived as better and more advanced than using candles, kerosene or even torches powered by batteries.

Activities such as reading in the evening have been made easier due to having a better-quality light in the house. Two PPWs participants mentioned they could now read the bible in the evening or early in the morning, while preparing for the morning bible study group meetings:

> "We always have church meetings around 4:30 in the morning. Because of the system, I am now able to prepare some readings before we meet. But before because I had to use kerosene sometimes, I could even fail to use matches to light the lantern because, for example, matches were too cold which made them hard to use." (Male participant, PPW11, Kayonza)

Figure 5.66. PPW11 participant in his home in Kayonza. Photo taken by his wife. Photo credit: I. Bisaga.

The change is not in the presence of light versus prior lack of it (as kerosene lanterns used to be used before) but rather in the source of light which is better, simpler to use and allows one to perform certain activities with a greater level of ease. Other routine activities such as looking for clothes or other items early in the morning while preparing for work have also been simplified as the need to carry around a kerosene lantern, a candle or a torch has been eliminated and the process of searching for objects is faster as both hands can be used, and brighter lights mean seeing or spotting things more easily. Being able to move around the house (both inside and outside) in the evening, without a fear of stepping onto objects lying on the floor or animals which can sometimes wander into the house (such as snakes in some areas) is another example of basic activities which study participants remarked as being more manageable than before they had a SSHS. This point is raised again under the impact of adopting an off-grid solar system on safety and security in section 5.4.5.

Both FGs participants and survey participants considered the ability to socialise with family and friends in the evening, over of after an evening meal, as an important way in which having the system has affected their lives. The social aspect of energy use does not emerge as a result of getting access to an improved source of energy but is reinvented instead. Families can now socialise longer and in a cleaner environment, devoid of smoke and fire hazards. Those who have a TV can watch it together and instead of going out to watch it elsewhere, they can do it at home. Having access to entertainment at home can also change behaviour, or routines. An example was shared by a woman whose husband used to watch football matches at a bar but can now watch them at home:

> “My children's father also stays home because he is able to watch football, he likes watching matches a lot. Before, especially during the world cup season, he used to go out and he would come back home around 1:00am but now he is able to watch it from home." (Female participant, PPW7, Musanze)

She further went on to say:

> “My daughter is still small as she is only three years old, but she likes watching TV.”

Children and adults alike appreciate the new entertainment and access to information options that come with the services offered by a SSHS. One of survey participants shared what entertainment he enjoyed that was provided by a TV which he got with his system:

> “I now watch news on TV, I watch football matches, and I watch music and movies on TV.” (Male participant, S3, Kidaho)

Another SSHS user who participated in one of the PPW brought up a number of points when discussing impact. He stated:

> “I adopted the system and now I can easily light my house. I can watch TV whether it's raining or not. My battery does not get drain. Kids are able to study and they like the brightness of the light and the fact that it is always stable.” (Male participant, PPW16, Gasiza)

His points speak to a number of aspects of impact on HH members, including children, which is discussed in more detail in the following section.

5.4.1 Children

In HHs where there were children, the main impacts on them were associated with the ability to study in a brighter and more comfortable environment, free of candle or kerosene smoke, and also improved as compared to the light provided by a torch, which translated into longer hours of studying as a result of the better environment in the house. 68.7% of survey participants said children studied longer as a result of having the system, for 21.5% it was not applicable as there were no children in the HH. 9.8% said they observed no change in the study hours of the children resulting from having the SSHS. For those who said the children did study longer, the average time by which the study time extended per day was 2.02 hrs.

FG2(7) participant explained the importance of clean and bright light for the children, saying:

> "[Children] are able to study with a safe light that does not reduce their sight." (Female participant, FG2(7), Gakoro)

Another one expressed a similar concern addressed by the improved lighting:

> "Their [children's] eyes have no risk of being affected by the smoke while studying." (Male participant, FG2(9), Karangara)

A PPW16 participant, the head of household, expressed his satisfaction with how the system, and particularly the ability to light up his house, affected his children:

> "System can light all my rooms. Kids are able to study in the evening. One of my kids is always the first in class because she is able to revise in the evening because of the system." (Male participant, PPW16, Gasiza)

A female SSHS owner who participated in PPW20 also shared how the system had changed their children's attitudes to studying:

> "My kids used to refuse to study in the evening telling me that they cannot study by a kerosene lamp. But now they are able to study because in the living room the lights are bright." (Female participant, PPW20, Nyanza)

Figure 5.67. Children in Gasiza posing to a photo enacting doing homework. Photo taken by their father, a participant of PPW16. Photo credit: I. Bisaga.

A couple (husband and wife) who participated in PPW9 noticed a difference in children's study routine as well, both their own and other children from the neighbourhood:

> "My wife is also able to cook, help kids to take shower in the evening. Before, it used to be very difficult because the lantern brightness could not reach all the places of the house. But with the system she can do all the activities from whichever side she wants. She can also wash dishes in the evening all this because of the brightness of the lights." (Male and female participants, PPW9, Musanze)

A better study environment was shared by both the children and the father in the case of PPW14 participant who said:

> "Kids are able to study. Even myself as I also pursue my university studies. Sometimes if I had forgotten to buy batteries I could spend a night in the darkness." (Male participant, PPW14, Gicumbi)

Figure 5.68. A boy revising his studies in Kayonza. Photo taken by his father, participant of PPW18. Photo credit: I. Bisaga.

Other impacts on the children included the ability to move around the house more freely, without the fear of stepping onto something or tripping over objects on the floor, as well as no risk of electrocution, which was mentioned by all the participants who had previously had access to the grid (prior to adopting a SSHS). Additionally, children's ability to play around the house in the evening, without the need of wandering off to other places to seek somewhere lit up, was also appreciated, as not only did it make it easier for the children to play around their own houses, but also reduced the worry of parents who were concerned about them being away often late into the evening. As explained by a male FG1(5) participant:

> "For me, I have 2 lights outside, and I often light them up for my grandchildren so that they can play in front of my ground in the evening instead of wandering off!" (Male participant, FG1(5), Gakoro)

Another customer said:

> "There are no more black outs compared to the grid. Children watch TV and movies in the evening which has been helpful for us since they stay at home." (Female participants, FG1(2), Bigogwe)

The household head who participated in PPW4, shared her content regarding children by saying:

> "I can switch on the light all day long and kids are so happy!" (Female participant, PPW4, Muhanga)

Participants who owned TVs also talked about how children enjoyed watching TV or movies, and how they were happy that the children could get access to information and 'the outside world', which they saw a TV to be a door to, in the absence of other avenues of accessing information and knowledge about the current affairs and the world more broadly, other than a radio in HHs where there was one.

5.4.2 Women

Both male and female participants spoke about the impact of having the system and using the appliances has on women and their daily lives.

Speaking on behalf of the members of the community who have adopted off-grid solar systems, this Village Chief shared his opinion on the change that has taken place:

> "It enormously helps our homes, because we no longer buy kerosene, students are studying, children no longer wander off, women do the evening activities in a lightened-up environment." (Male participant, FG1(2), Bigogwe)

Some of those sentiments were shared by a female participant of one of the PPWs in the Eastern Province:

> "What changed in my life is that I can now work in a bright place. Sometimes when I take a trip out I don't fear coming back late in the evening. When I go somewhere, I can leave the light on, without fearing that at some point the light will be off, and later in the evening when I

> come back the lights are still on and kids are playing around." (Female participant, PPW1, Nyamata)

Same woman added:

> "But before, I could cook holding my child in the back and also holding the other one in my arm so that they don't step into animal because in this region we have snakes which could bite our children because they could not see it." (Female participant, PPW1, Nyamata)

Figure 5.69. Participant of PPW1 in Nyamata posing for a photo with her child in front of the back-house door, with the outdoor security light above their heads. Photo credit: M. Uwase.

In all five FGs (FG2(6-10), when asked about safety and how it had been impacted post SSHS-adoption, and what it meant for different household members (which is further discussed in section 5.4.5), participants said that women were able to cook dinner in a lit up place, which made it safer for them as they could see everything around them (e.g. kitchen utensils), no longer had to hold a source of light (such as a lantern, a candle or a torch) while cooking, which freed up their hands, and were able to avoid risks associated with candles or lanterns tipping over, which could occasionally result in burns. Even though the cooking itself continued to be done with wood fire or other smoke-producing sources, the act of cooking was made safer due to the light provided by the system.

While discussing impact and the most significant changes that have occurred in the HH since having the system installed, one male participant also explained how and why his wife encouraged the purchase of the SSHS:

> “It's my wife who pushed me to buy the system. The biggest change that has happened is that she now enters a bright place. There is another big challenge that she used to face. Whenever we could afford a torch, my wife would do some activities holding that torch in her mouth, for example to cook, and she used to tell me that she was feeling pain and we were always wondering how we would explain to the doctors about her illness. I would also wonder how this was going to end. But now she no longer holds a torch in her mouth and she also tells me that she no longer feels pain. She can also testify herself, it is not a joke!” (Male participant, PPW2, Nyamata)

His account not only speaks to the question of who in the HH contributed to, or even initiated, the decision-making process of getting a SSHS, but also who then has been the key beneficiary of the services it provides. Despite the man being the breadwinner, as often remains the case in rural HHs across Rwanda, the voice of the woman was proven to be the important one for her needs to be recognised and her preferences to be expressed, ultimately leading to the adoption of a modern energy source which has eased her daily activities and had a positive impact on her health and well-being by eliminating previous practices which were proving harmful (i.e. causing physical pain).

One female participant of a PPW in the Musanze area, who had given birth a few weeks before the workshop took place, explained what changes she experienced since adopting the system:

> “I do all my activities in a bright place and now that I gave birth; the place is bright. The fact that the place is bright it is enough for me.” (Female participant, PPW7, Musanze)

She also confessed that nursing her baby, particularly when it wakes up in the middle of the night, is now much easier because of the bright light which she can turn on very easily without having to move far or step out of the room. The below photo reflects what she was very satisfied with: the brightness of the lights. It was taken in the evening hours when it was already completely dark outside.

Figure 5.70. Participant of PPW7 with her new-born baby posing for a photo taken by her daughter in her bedroom, with the system light on. Photo credit: M. Uwase.

Due to hazards posed by lighting sources such as kerosene lanterns or candles, she would usually nurse her baby in darkness before the system was adopted, or with the use of a battery-powered torch if it was available at hand and functioning (i.e. it had battery power).

The improved ability to perform different activities around the house has also been observed by the husband who, together with his wife, participated in a PPW in the Musanze area:

> "My wife is also able to cook, help kids to take shower in the evening. Before, it used to be very difficult because the lantern brightness could not reach all the places of the house. But with the system she can do all the activities from whichever side she wants. She can also wash dishes in

> the evening all this because of the brightness of the lights." (Male participant, PPW8, Musanze)

Again, her case shows that light has enabled the woman in the HH to carry out the same activities she used to perform before, however, now with a much greater level of ease as the environment in which she operates in, compared to the one before the system was used in the house, has improved, letting her perform tasks or chores more swiftly and making them less burdensome.

Female study participants (in the survey, FGs and PPWs), as the ones responsible for a majority of household chores, have also stressed the value of having additional hours of reliable, bright light available in the evening for the re-shuffling of chores from early morning hours to the evening (instead of waking up early in the morning to perform certain activities while it is light outside in order to be able to complete all tasks by dawn) and the overall increased flexibility of doing chores (according to their needs and/or preferences) throughout the day and later into the evening, and how that impacted on their daily routines.

Other impacts associated with the extension of productive hours, or hours of light, into the evening are further discussed in the subsequent section.

5.4.3 Extension of light/productive hours

The extension of light hours, which corresponds to the extension of productive hours, whether for income generation or for other activities, has been reported as an impact across all groups of study participants. The impacts can be organised into the following categories:

a) Reshuffling of pre-existing activities (e.g. chores, cooking etc.) due to the longer hours of light in the evening;
b) Undertaking of new activities in the evening hours which can now be utilised due to the improved source of light; those activities can either be income-generating or non-income generating;
c) Extension of pre-existing (predominantly income-generating or productive) day activities due to the added hours of light in the evening, either inside the

home (e.g. business ran from home, food processing etc.) or outside (e.g. a day job, work in the field etc., as well as use of the system in a work place such as a bar or a shop); other activities which required light, or were more easily carried out in the hours of daylight/had to be done before dusk, can now be performed later in the evening;

d) An enabling environment in which activities can be performed with a greater ease due to the improved and extended hours of light (e.g. previously cooking in darkness or with a poor lighting source vs cooking in a brighter place); if activities were habitually performed in the evening hours (whether out of choice or due to external factors, such as late working hours), they can now be performed more easily, in a faster and safer manner.

Examples of the above are reflected in the feedback shared by participants of FGs and PPWs in particular, as well as survey respondents where opportunities to provide qualitative insights were offered.

One of FG1(5) participants indicated the way in which his productive hours had been extended and what it had meant for him, by talking about the new activities he was now able to carry out:

> "I currently work in the evening such as repairing shoes, sorting through dried beans, while I could not before which increased the productivity. I do most of those activities because I can light up longer till around 21-22 hours. And I could not do this before because the lighting of candles, paraffin or lantern lamps is not bright." (Male participant, FG1(5), Gakoro)

Figure 5.71. Participants of PPW6 in Gakenke at their home, demonstrating how they sort through corn knobs as an income-generating activity, with which the system light helps in the evening. Photo credit: I. Bisaga.

A PPW participant, who ran his business of cutting tyres from home, also noticed how the system impacted on his working hours and the increased productivity, and beyond:

> "There is a big difference, for example I always keep the lights on and we don't get switched off. We can also work until late in the evening unlike when we were using the torch batteries because we used to fear that the batteries would get drained. I can also listen to music as compared to before. My torch batteries used to drain so fast and it was so expensive. But now I can watch TV, listen to the news all over the world. Many things have really changed that drove me to get rid of kerosene." (Male participant, PPW8, Musanze)

Figure 5.72. Participants of PPW8 in Musanze demonstrating tyre-cutting which is their business. System light extends their working hours into the evening. Photo credit: M. Uwase.

Due to the increase of working hours by 3-4 hours, on average, per day, he had managed to grow his business and had to employ two new workers to help out with the operations. While before he used to end work around 6-7pm, he could now continue until 9-10pm, which resulted in a considerable increase in the volume of processed tyres and the need for extra manpower.

A male PPW participant in Gicumbi, who was using his system to run a bar, shared how access to a reliable source of lighting impacted on his business and business-related expenditures:

> "Before I used to light the candles or use kerosene from 6:00pm and I could spend RWF200 or I could even spend RWF250, if I had many clients, per day. But now I can switch on the system around 6:00pm until 10:00pm and the clients are always happy. Sometimes when it's a sunny day the battery doesn't drain. [Now] it's not the same, before I could use the candle and the wind could put it off, and we could stay in the darkness. But with the system the place looks good and bright, and the number of clients increases." (Male participant, PPW12, Gicumbi)

Business improvement was multi-faceted: expenditures on light sources were cut down, satisfaction of clients increased and so did the number of clients, which resulted in higher income.

An FG participant, while discussing observed changes stemming from the use of the system and more specifically the portable torch light, said:

> "I can work in my farm late in the evening." (Male participant, FG1(3), Cyuve)

Women voiced their content with the fact that they could wash clothes in the evening instead of having to do it earlier in the day, sometimes having to wake up early in the morning so that they could do it in the daylight, knowing they would not have the time later in the day before it gets dark. In a similar way having lights around the house impacted on cooking, as mentioned in the previous section, and as shared by female FGs and PPWs participants. With the improved lighting, they were now more comfortable cooking after dusk due to the brighter environment in the house.

Extended hours of light also translate into benefits such as socialising with family and friends in the evening:

> "We now light, we now take beer from home, chat longer with our friends since they can stay longer late in the evening." (Male participant, FG1(1), Nyarubuye)

Although unspecified in nature, another participant confirmed he was able to carry out productive activities in the evening, and socialise with family, also by using other appliances, including a TV which is a medium of news and entertainment:

> "I can do productivities until late in the evening. Together with the family we can watch TV and listen to the news." (Male participant, PPW8, Musanze)

A female participant of a PPW shared how having phone charging available to her at home has freed up time for other activities by saying:

“I am now able to charge my phones without having to travel a long distance. It saves me a lot of time.” (Female participant, PPW10, Kayonza)

Figure 5.73. PPW2 participant demonstrating phone charging with his SSHS. Photo taken by his wife. Photo credit: I. Bisaga.

Figure 5.74. PPW10 participant in Kayonza took this photo of the system to demonstrate how he charges his phone. Photo credit: I. Bisaga.

The male participant of PPW11 in Kayonza who can now read the bible before his early morning church meetings also saw this extra time with a reliable source of light he had gained as a result of adopting the system as productive. Preparation for those meetings used to be much more difficult with the light of a candle and, as he mentioned, sometimes he would not be able to light up at all or in instances where he had forgotten to buy candles, he would have no way to read early in the morning.

5.4.4 Savings: time and money

Time and money savings manifest themselves in various ways, as has partially been discussed in the previous section. Time savings are considerable across the survey sample with an average of 2.08hrs saved per day (median=2hrs). Men report saving, on average, 2.13hrs per day while women report time savings of 1.94hrs per day. Time savings predominantly stem from the replacement of certain activities by the system. Among those activities are the need to charge a phone or phones outside of the home, which includes the time spent traveling to get to the charging station (a return trip) and the time it takes to charge the phone, which adds a wait time, and the time required to purchase lighting sources, such as candles, kerosene for lanterns, or batteries for torches. Time is also saved through the reshuffling of daytime activities which can now be pushed into the evening, as discussed in section 5.4.3. The ability to reschedule tasks which can now be completed in the evening, in a sufficiently bright environment, means that time during the day can be used for other activities, such as extending time worked on a farm. Additionally, with the services provided by the system, time can also be saved by allowing certain activities to be performed faster and in a more efficient manner. One example of that was shared by a customer who sorts corn grains at home (Figure 5.71 in section 5.4.3) and can now achieve his daily target faster as with the light in the evening he can see better and sort through more corn in a shorter amount of time. Another one, who is an accountant, demonstrated how he can now draw his tables more precisely, and do the calculations with more ease as he can see better when he does it in the evening. A well-lit place allows him to perform his work more diligently and faster than before (male participant, PPW16, Gasiza).

Figure 5.75. PPW16 participant in Gasiza showing his accounting books which he can now do with more precision thanks to improved lighting in the evening. Photo taken by his wife. Photo credit: I. Bisaga.

A participant of FG1(2), who used to be connected to the grid, shared his experience of time saving which came from no longer having blackouts at his home, which would cause a loss of time as he would be left in darkness at times when they occurred, making it difficult or impossible to work or perform other activities.

> "There are no more black outs compared to the grid." (Male participant, FG1(2), Bigogwe)

Another participant of the same FG commented on the impact the system had on her HH, including the time and money saving due to charging phones at home and reducing expenditure on other sources:

> "Now I charge at my home, I no longer buy batteries for my radio, we also used to cook in darkness." (Female participant, FG1(2), Bigogwe)

"Saving money" was the second most often mentioned way in which users' lives have been affected by having a SSHS (34% of survey respondents) after having light. Financial savings predominantly stem from three previous expenditures, which also link to time savings:

i) reduction/elimination of spend on candles, kerosene, batteries or other fuels for lighting and small appliances such as radios;
ii) reduction/elimination of spend on phone charging; and
iii) reduction/elimination of spend on transport costs associated with purchases of energy fuels and services (such as phone charging).

Various scenarios were expressed by several study participants who noticed the change in HH expenditures, or business expenditures in the cases where the SSHS was used for business purposes. A customer in Musanze pointed out to what he used to spend a lot on before:

> "I no longer spend a lot of money buying the candles." (Male participant, PPW9, Musanze)

A female participant in Muhanga also shared what made up a portion of her expenditures prior to adopting the system:

> "We've been here for 1 year and two months. Before that time, we were consuming a lot of energy, we used to spend a lot on batteries as compared to now. But now we have been able to save which has allowed us to purchase a cow which now enables us to sell milk and fertilizers to our neighbours." (Female participant, PPW3, Muhanga)

In the case of PPW3 participant, savings which resulted from having the system were subsequently used to invest in a cow which has enabled two new activities for income generation: selling milk and production of a fertiliser. Another PPW participant also shared her story of how she started making savings, and learnt how to put money aside:

> "I used to buy candles and kerosene everyday which has now reduced. Again, I used to pay a lot of money buying different things but now I learnt how to make savings so that I can be able to make the monthly payment for the system. In the recent past, I got a problem, my dad fell sick. He was here last December. I took him to Kabgayi hospital.

> Afterwards, he came back home. So, I was able to use the money that I had saved to help him during his sickness." (Female participant, PPW4, Muhanga)

In this example, savings were made because the participant learnt about the importance of saving up and how to do it, which not only allowed her to make sure she was always able to make the monthly payment, but also generated a buffer for a time of emergency which was the need to hospitalise her father, for which she was able to pay due to the savings she had made. In the workshop discussion she also revealed that from the savings she generated, she purchased a cow, which she felt was a big asset for the HH.

Figure 5.76. PPW4 participant in Muhanga taking a photo of her grandchild with a cow she purchased with the savings made thanks to having a SSHS. Photo credit: I. Bisaga.

One other workshop participant talked about the savings he started making after adopting a SSHS, providing a breakdown of what he used to spend before:

> "Yes, I am able to make savings. Before I used to use two candles per day which makes a total of 14 candles/week. Each day I was spending a RWF100 but now because of the solar lights, I can save a lot of money which I mostly use in my farming activities." (Male participant, PPW18, Kayonza)

Similarly, as in the previous two cases where savings were invested in stock, this customer has channelled them into productive activities. In another instance of a participant who felt his expenditure on energy had reduced, shared how by generating income from his system by charging other people's phones he is able to make enough to make the system payment every month and sometimes make extra:

> "There is a difference between having the system now and before I purchase the system. Before I used to spend a lot of money. However, after adopting the system as I have to pay RWF5,850 per month, sometimes it's difficult to make all the payment in one go, especially that I might not have a job. So, I am able to pay little by little and finish my payment at the end of the month. Sometimes there is also benefits, because if people bring their phone for charging, I charge them RWF50 and at the end of the month I can realise that I am paying the money that I got from the charging fees. So, as you can see you are prospering." (Male participant, PPW17, Gasiza)

Figure 5.77. PPW17 participant in Gasiza posing for a photo with the light on (left) and demonstrating where he keeps his system (right). Photo credit: I. Bisaga.

A customer in Nyamata, whose wife used to suffer from jaw pain from holding a torch in her mouth, also showed off his rabbits which he was able to buy as a result of savings he made after purchasing the system. Those savings mainly came from no longer paying for kerosene and candles, and for phone charging.

Figure 5.78. PPW2 participant in Nyamata showing off his rabbits he purchased thanks to savings he made on candles, kerosene and mobile phone charging since he got his SSHS. Photo taken by his wife. Photo credit: I. Bisaga.

A business owner in Gicumbi also provided a breakdown of what he used to spend on candles and kerosene for his bar before the system:

> "Before I used to light the candles or use kerosene from 6:00pm and I could spend RWF200 or I could even spend RWF250, if I had many clients, per day."[41] (Male participant, PPW12, Gicumbi)

At RWF200 per day, he was spending, on average, approximately RWF6000 per month (and approximately RWF7500 per month when spending RWF250 per day). With the SSHS installed at his bar and a price of RWF3900 per month, he expressed

[41] Quote also cited in section 5.4.3.

satisfaction with the reduction of expenditure on lighting and the ability to better serve his clients. His case was also discussed in earlier section (section 5.4.3).

In Nyanza, a female PPW participant, who also has a grid connection in her house, spoke about how she used to buy a lot of batteries to power off many torches which were needed for everyone in the HH to have access to light. She asserted:

> "I bought the system because here when it rains especially with the thunderstorms, the [grid] power goes off and we need to buy torches. I normally don't buy candles because of the children. So, I always had to use many batteries for all the rooms which is so expensive, and the batteries don't even last for long but now when the electricity from the grid goes off the system is always on." (Female participants, PPW19, Nyanza)

Figure 5.79. PPW19 participants (a mother and a daughter) in Nyanza posing to a photo with their outdoor light on. Photo taken by another daughter. Photo credit: I. Bisaga.

Participants in FG1(1) also discussed the issue of phone batteries being stolen while having their phones charged, which could create a financial burden as they would have to be replaced (good batteries would be swapped for older/poorly-functioning batteries), new phones would have to be purchased or the swapped batteries would have to be charged more often due to low capacity of holding power, thus lasting much shorter than newer/well-functioning batteries. This aspect was also considered to be a saving, as well as a matter of security by decreasing, or eliminating, the risk of such a situation happening again as they were now able to charge their phones at home.

The question of savings was discussed in all five follow up FGs (FG2(6-10)) to understand whether those who have adopted SSHSs do save because of having the system, as well as why and how much they do, if yes. In FG2(6), FG2(8) and FG2(9) all participants said they do save up now that they have the system, mostly because they used to spend a lot on candles and kerosene, and phone charging, which was reduced after SSHS adoption. In FG2(8), some participants were involved in income-generating activities with the use of the system which helped make savings. Among FG2(10) participants, three said they were saving now that they have a SSHS, 2 said they were still spending the same as before, and one person said they were now spending more than before. Having calculated, the three who felt they were making savings arrived at Rwf1500-2000 per month saved. The one who felt was spending more calculated that he was spending RWF1400 more per month than he used to before having the system. In most cases participating system users did not calculate the amounts prior and post system adoption but those who declared they were saving because of the system frequently said that: "[…] we don't calculate but deep down we know we are saving." There was a sense that savings were made even if there was no factual ground for it. In two other FGs (FG2(8) and FG2(9)) most participants declared that they did not calculate the savings. Two in FG2(8) did the calculation at the time of the discussion and found that they were saving between RWF100-130 per day, whereas the one who did a similar calculation in FG2(9) found that he was saving RWF2000 per month. In the other two FGs (FG2(6) and FG2(7)) everyone reported that they did not ever make such calculations, with a couple of participants in FG2(6) saying that "[…] deep inside they know they are getting benefits from the system." In FG2(7) voices were more varied, with a split between reporting that the expenses on energy fuels or services replaced by the system were the same as before or more than before. One participant said that he would "[…] save after 3 years", meaning after paying off the system (assuming full ownership and no ESF). One participant of FG2(7) explained why some customers feel they pay more than they used to. He linked it to the fact that some used to get certain services for free, for example phone charging, which they do not have to pay for with the system, but that cost was not there in the first place, so it makes no difference as there was no cost to be eliminated. From his point of view, it was the opposite with that cost being now included in the price they pay for the system, effectively making it an additional cost.

Overall, when financial savings are made, they are mostly generated in two ways:

i) Actual savings resulting from lower expenditure on lighting sources and phone charging (incl. money spent on transport when going to charge a phone or purchase lighting fuels, etc.);
ii) Saving behaviour which results in (higher) savings.

5.4.5 Safety and security

98.5% of survey respondents said they felt safer because of having the system and, more specifically, the lights which are used as security outdoor lights, as well as indoor lights in all or selected rooms/areas, depending on the number of light bulbs owned. This result stands in contrast to the results shown in Figure 5.64 where only 0.8% of survey respondents said that improved safety was one of the ways in which having the system had impacted on their lives. That question, however, was asked first and was an open-ended one, where respondents were free to list out any impacts they could think of or that came to mind at that point. Safety was not among the top impacts then. However, when explicitly asked about whether they feel safer as a result of having the system, their focus shifted to the issues around safety more specifically. While having light, saving money and socialising with family and friends were the top three most commonly listen impacts in the open-ended question, feeling safer was indeed shown to be a significant impact when prompted about safety explicitly.

For those who used to have a grid connection (and in some instances continue to have that connection post system adoption) the safety aspect was associated with no risk of electrocution, as opposed to having that risk in on-grid electricity. A PPW participant in Gasiza described it, saying:

> "I can't use on-grid system in my room because there is risk of electrocution. But I realised that off-grid system is safe and there is no risk of fire. Whatever I can plug into the system I always feel safe, I can't get burnt or electrocuted. It's not similar to on-grid because their sockets

can have the short electrical circuit. For example, that switch got a short electrical circuit and the only thing I did was to just turn on the switch."
(Male participant, PPW15, Gasiza)

Figure 5.80. A switch in PPW15 participant's house which burnt having experience a short electrical circuit. Photo credit: I. Bisaga.

A discussion during FG2s revealed the key perceived hazards, in addition to the risk of electrocution among grid-connected users, which included:

a) Darkness and the fear of/inability to safely move around the house (indoors and outdoors) because of the risk of tripping over objects invisible in darkness, stepping onto wild animals which enter the property (such as snakes) etc., as well as the fear of stepping outside of the house at night (e.g. to go to the toilet);
b) Fire hazards created by using candles or kerosene lamps indoors, and the risk of objects (clothes, bedsheets, etc.) catching fire or HH members getting burnt by the flames;
c) Smoke and its negative effects (such as on the respiratory system and eyesight) on HH members, e.g. children studying by kerosene lamps or candles;
d) Thieves who cannot be seen or deterred without available lighting, particularly outdoors;

e) Risk of having cables or other electrical connection components stolen in the case of on-grid electricity (but not in the case of a SHS, as perceived by the participants);

Additionally, FG participants also considered the security of supply as an important aspect of having a SSHS vs a grid-connection or the use of other lighting fuels which can run out, sometimes in the evening time, leaving HH members in darkness. Knowing that as long as you do not fail to make the payment you will not get disconnected from the power supply was perceived as a safety issue.

A PPW participant who had no electricity prior to adopting the SSHS and used to rely on a kerosene lantern, said:

> "I used to use kerosene and I could not go to the toilet or even outside in the evening, I was scared. But now I have put lights outside and inside the house, I am no longer afraid to go out." (Female participant, PPW20, Nyanza)

Another SSHS user who participated in FG1(1) stressed:

> "[Now] I am able to guard my domestic animals, mostly chickens, from predators." (Male participant, FG1(1), Nyarubuye)

One other participant of the same FG referred to the threat of thieves, sharing:

> "Most of the time a thief runs away when they see the light on. I am also not afraid to go outside when thieves are out there because the light is on." (Male participant, FG2(6), Raba)

The question of safety and security was also mentioned by survey participants who spoke had the opportunity to elaborate on the impact the system had on their children. In addition to what has been discussed in section 5.4.1, respondents also reported aspects associated with a safer environment for their children, as was the case of an example provided by a male respondent in Kidaho:

> "Now my kids can go out to toilet and they don't fear anything because there is light." (Male survey participant, Kidaho)

The already mentioned reduction of risk of electrocution among children in HHs where there used to be a grid connection, or in those where a grid connection was considered but there was a fear of the risk of electrocution, was noted by nearly all participants in those circumstances who had children. In FG2s the concern was discussed in 3 out of 5 FGs, with participants stressing that children can sometimes play around the system and either touch it or move it, but it causes no worries as they cannot get electrocuted, as opposed to the risk that if they touch a socket it may happen. Similarly, in 3 out of 5 FG2s no risk of electrocution was considered one of the most important benefits of having the system, particularly for children and women who are often present in the house while children play but no longer have to closely watch over them as there is no fire or electrocution hazard. Finally, having the peace of mind at night due to the safer environment (no fire and electrocution hazard), improved by the presence of the system, was highlighted as a benefit, most importantly for women.

5.4.6 Challenges

Despite numerous impacts which can be considered positive for the HHs adopting SSHSs, there remain challenges associated with having the system, both when using it at times when all payments are made and completed on time, and when payments are missed, and the system gets switched off. The latter is briefly discussed in section 5.4.6.1.

The pricing of the system and its various types (or packages) at the time of this study was one of the major concerns among study participants. It was considered too high by over 50% of survey respondents and approximately 55% of all FGs participants. The irregularity of income, as well as unforeseeable circumstances beyond customers' control, which can put a lot of strain on the limited monthly budgets, cause payment delays or impact on the payment ability for times longer than the grace period offered by the provider, ultimately resulting in delinquency, defaults and repossessions. It was reflected on by survey participants who shared the following:

> "I would like them [BBOXX] to understand my reason before they switch off, I have been sick for a while and I can't find money for the moment." (Male respondent, S3, Ruli)

Another one said:

> "I would like to pay like three months during the harvest, I don't like the monthly payment system even people in our village, they don't like it." (Male respondent, S2, Mahoko)[42]

Another challenge which was mentioned by two survey respondents, but which has considerable (negative) consequences for HH members, relates to the rearrangement of the HH expenditures:

> "The quantity of food they [children] eat now compared to before has decreased, as well as clothing. The money used for that now is used for BBOXX subscription." (Male respondent, S2, Kabaya)

The concern shared by the other respondent who encountered a similar challenge was that there was now less money available for food in the HH as compared to before the system was adopted. Even though he was satisfied with the benefits offered by the system, he and his family felt the strain put on them as a result of having the system. The redistribution and reprioritisation of the key expenses in the HH among study participants can be seen in section 5.3.5.

Related to the above, in that there has been an observed stress on the budget, was the expressed concern about the effects of not having enough light bulbs. Some HHs where the number of rooms in the house is higher than the number of available light bulbs have to resort to buying other lighting fuels, as expressed by a survey respondent:

> "I need more lights because I always have to buy batteries [for torches] for the remaining room." (Male respondent, S3, Musanze)

The same sentiment was shared by some of the other participants who expressed the need for more light bulbs so that they can light their whole homes rather than just selected rooms. The insufficient number of lights can mean having to spend extra resources on lighting fuels in addition to the SSHS, which effectively results in

[42] Quote also cited in section 5.2.5.

increased expenditure on lighting when compared to that from the time prior to system adoption.

The inability to get additional appliances (i.e. upgrade their systems), mainly due to being rejected for an upgrade at a provider's shop (because of not meeting the required length of time which makes a customer eligible for one or for other undisclosed reasons) was reported by individual FGs participants (5 in total) and by 10 out of 265 survey respondents (3.8%). The four main desired appliances were TVs, radios, torch light and light bulbs. The number of those customers does not carry statistical significance; however, it also points to upgrade efforts from the customers' end to a higher degree than what is reflected in the number of actual upgrades (1 survey respondent upgraded between September 2016 and 2017) pointing to the prohibitive policies for upgrades as potentially another reason for the low appliance uptake, in addition to the challenge of affordability and the lack of willingness to upgrade. The frustration and dissatisfaction associated with the inability to purchase additional appliances (whether on a subscription model or off the shelf) might be detrimental to the customer retention rates as dissatisfied users might seek alternatives elsewhere where the desired set of appliances can be obtained, or otherwise attempt to connect non-compatible appliances to the systems, increasing the risk of misuse and damage.

One other challenge observed among all study participants was the question of warranty, including the ESF which, at the time of data collection in 2016 had only just been introduced but by the time PPWs were conducted applied to majority of all customers. There was a visible confusion and lack of clarity and information on what the ESF was. Dissatisfaction was expressed in regard to the obligation to continue paying after the 3 years of the original subscription, or repayment period, which was the set period after which customers were supposed to get the full ownership of the product, prior to the introduction of the ESF. Customers' voices were divided into four distinct groups:

i) Those who did not want to subscribe to it at all but were aware of the ESF;
ii) Those who wanted it as they felt there was a value in having a warranty after the 3 years but believed the price of it should be reduced;

iii) Those who wanted warranty as they were concerned about what would happen after the 3 years were up but were unaware of the ESF; and

iv) Those who did not want warranty at all and were unaware of the ESF.

While there was no strong association between respondents who had experienced technical issues with their systems combined with the use of after-sales services (including repairs) and the willingness to subscribe to the ESF, participants in FGs and PPWs who spoke about the warranty issue and expressed appreciation for it tended to be those who had been using their systems for a longer period of time (over 6 months) and included those who had used after-sales services (e.g. system repair).

5.4.6.1 Switch-offs and breakdowns

Systems switch-offs, which primarily result from late payments, as well as system breakdowns or technical issues (e.g. non-functioning battery or problems with a TV, or any other appliance) have an impact on the HH in at least four different ways:

i) HH have to resort to lighting sources they used to rely on before, such as candles, kerosene lanterns or torches (for which batteries are needed), which can be costly yet adjusted for the available resources (i.e. a HH may decide to only light for a short time in the evening if they can only afford one candle or want to save up battery power in a torch for it to last longer);

ii) In the case of breakdowns, there is a cost associated with taking the system (or any of its components that is experiencing a fault) to the shop and then bring it back once it is repaired, which can be costly (on average, between RWF1000-2000 for a return trip);

iii) The time without the services offered by the system may impact on the daily activities, including business or income-generating activities (e.g. reliance on a mobile phone for business is compromised if the phone cannot stay charged);

iv) The time they are switched off due to late payments means they have to make up for it when they are next able to make the payment, meaning they have to pay retrospectively for the days they missed and were switched off, effectively paying for the time they did not have electricity in their home; this can cause a considerable financial burden and, once a payment is missed, participants reported finding it difficult to recover and catch up with their payments, which accumulate over the switch-off period.

One participant in FG1(3) described what impact having the system switched off had on his activities:

> "I lost clients as some of the clients used to come to get benefits from the services such as charging phones or watching TV but when the system stopped working, I lost them." (Male participant, FG1(3), Cyuve)

Another one in the same FG said:

> "The biggest implications [of the system being off] was time- I had to close my shop." (Female participant, FG1(3), Cyuve)

When discussing the implication of system switch-offs and times when a system was getting repaired or stopped functioning, FG participants in Gakoro shared their experiences:

> "We had to buy the alternatives such as candles, and kerosene." (Male participant, FG1(5), Gakoro)

> "I had to charge my phone with someone else, and travel to the shop to get replacements." (Male participant, FG1(5), Gakoro)

> "In the signed contract, it is written that the reparation is for free, but we always pay for transport to take the system to the shop." (Female survey participant, Kidaho)

A participant in Nyarubuye referred to the days he had to pay for during which he was not able to use the system:

> "The impact on me was that I also pay for the days I did not use because the system was off due to late payments." (Male participant, FG1(1), Nyarubuye)

The cost implication of having to resort to other appliances and energy sources was expressed by a participant in Nyagahinga:

"We have to pay money to buy other appliances and yet we are still paying monthly for the system which is not in use. It is difficult." (Male participant, FG1(4), Nyagahinga)

Among TV owners, particularly in areas with a weak TV signal, customers found it challenging to continue paying for a TV system package while they were not able to watch TV yet were also unable to return it and switch to a smaller package. The high cost associated with owning a TV and the inability to channel those resources from a non-functioning appliance to other needs was expressed as a challenge among customers experiencing signal issues or a complete lack of signal.

At times when the SSHS stops working or is switched off due to late payment, the positive impacts and benefits which can be drawn from the system and the offered services are cancelled and majority of HHs where there is no other modern energy access option (e.g. grid or another SHS) experience a transition back to the status quo from before system adoption.

5.5 Chapter summary and discussion

This chapter has probed the personal domain of the energy use profile, focusing on the habits and experience associated with the use of SSHSs, the energy use behaviour and power consumption, attitudes towards and satisfaction with off-grid solar energy services, devices and carriers, end-users' needs and aspirations regarding energy access, and key impacts access to SSHSs has on the adopting HHs, which make up the human dimension of energy use and reflect the lived experiences and realities of end-users.

A considerable number of participants have reported running out of system power, particularly in the evenings and in the rainy season. Some Group 1 customers also observed the difference in the time the battery would last when they first started using the system vs at the time of data collection, over a year later. The noticeable change of degrading battery capacity over its lifetime has implications for users' experience as the battery goes through numerous cycles. As certain habits and routines around the use of the system develop relatively early post adoption, they might be compromised and put under stress if the system capacity decreases and it can no longer be used for as long as in the initial months or years.

Women report using the systems more than men. The key reason is that they tend to spend more time at home than men who use the system the most in the evening, after work. Children also benefit from the system more than men as, similarly to women, they spend more time at home. This finding is in line with other studies conducted on energy users which explored the gender aspect of energy access. Most recently, Fingleton-Smith (2018) has looked at the women's and men's traditional roles in the Kenyan society, and what they mean for how energy is used and perceived by the two genders. She has found that men are the ones in charge of decisions regarding energy access solutions for the households but they do not benefit from them in the same way as women do as they are home less than their female counterparts. Reddy & Nathan (2013) have analysed gender dynamics in Indian HHs concluding that women are the ones at the receiving end of energy poverty as they are the ones carrying the burden of lacking energy services, which aggravates and reinforces gender inequalities, thus hindering women's development. Ryan (2014) has called for increased inclusion of gender (and identity) in energy research and policymaking as women are disproportionately impacted by unsafe and often inefficient indoor energy sources, predominantly those used for lighting and cooking. This study has also revealed the disparity of energy use between men and women, and the impacts it has on both. As a result, the personal domain of female and male users of SSHSs are shaped differently due to the various levels of interactions with the energy services and devices, and different levels of assumed responsibilities with men more likely to oversee system maintenance and payments, despite women using the system more. Daily routines and habits shift for both genders, however, the shift is more pronounced for women than men. Even though Rwanda has a progressive policy framework which promotes gender equality and women's empowerment, there remain major barriers to achieving gender equality and implementing the existing laws and policies (Abbott et al., 2015). Among them the "[…] deeply embedded cultural values and practices that continue to construct women as 'naturally inferior'" (ibid., p.5) and the traditional gender roles which continue to be reinforced in the society, particularly in the rural areas. Therefore, the contextual domain, which is also the space of policies, laws and regulations, and the shared one in which cultural values exist, shape the personal domain of both genders and the individual capabilities, as well as the above-mentioned habits and experiences (including social practices).

Previously used lighting fuels still continue to be present in instances where there are not enough light bulbs to light up all the rooms in the house and in times when the system malfunctions, breaks down or is switched off due to missed payments. The latter instances, i.e. when the energy services provided by a SSHS cannot be used or become very limited, social practices tend to shift back to those prevalent in the time prior to SSHS adoption, as the need for services such as lighting and mobile phone charging are still present. System switch-offs due to unsettled payments occur among users of SSHSs despite evidence presented in this research which points to the prioritisation of system payments among monthly expenses which an average HH has to bear. The system along with expenses on food and school fees are among the top priorities for HHs. Unpredictable circumstances, or circumstances which are beyond one's control (such as job loss or a temporary work, poor crops, funeral or sickness in the family, other unexpected lump-sum expenditures or natural disasters, such as landslides, etc.) tend to impact on the ability to pay and result in system switch-offs. Participants have voiced the need for not only offering flexible payments but also grace periods which can help regain the services by catching up with missed payments rather than having their systems repossessed. Although having a SSHS can become a financial burden on HHs, it can also boost HH's finances in several different ways:

1) Starting a business (e.g. phone charging);
2) Extending opening hours of an existing business (lighting);
3) Attracting more customers with a new appliance (e.g. TV in a bar);
4) Enabling more efficient operation of an activity (e.g. improved lighting, reliable phone charge status);
5) Increased access to information (e.g. through TV, radio);
6) Extending productive hours at home (lighting);
7) Rescheduling of daily routines (e.g. elimination of the need to spend time on phone charging or buying candles/kerosene which result in time saving), giving way to longer hours of productivity (increased flexibility).

Additionally, money saving behaviour can develop or improve as a result of having to pay for the system regularly in order not to lose the energy services it provides. HHs where savings are made, or new income streams are created also reinvest resources into other assets (e.g. livestock) which might, in return, enable more productive, income-generating activities (e.g. selling fertiliser).

Men are on average more satisfied with SHSs than women, which links to the gender aspect of SSHS use where the woman interacts with the system more, on average, than the man and is therefore more likely to experience times when the system power is insufficient to meet all the needs or other potential issues or problems. Those using their systems for the longest period (Group 1) are, on average, more satisfied than those in the other two groups. The number of appliances included in the system package, however, has not been found to determine satisfaction. Neither has it been found to determine the amount of power consumed, on average, by the HHs. Power consumption is dynamic and does not increase in a linear manner over time or with more available appliances. This research has shown that adopters with fewer appliances get the most value for money from their systems, being also among those more entrepreneurial and using their SSHSs for income generation more often than HHs who have adopted systems with a higher number of appliances. Mobile phone charging and the use of light are the top two applications of energy services most commonly used for income generation among those who declared using their systems for income-generating activities, and aspirations for such uses in the future are present among nearly 60% of survey respondents who were not using their systems for such activities at the time of data collection. Women have been shown to be more likely to be willing to get involved in such activities than men. Other than aspirations for income generation, the aspiration for eventually getting connected to the grid has also been expressed, although by fewer than 50% of study participants. The results of this study show that those who adopt energy access solutions such as SSHSs fall into five distinct groups:

1. Those who will connect to the grid when an opportunity arises and discontinue using their SSHS;
2. Those who will connect to the grid when an opportunity arises and continue to use their SSHS;

3. Those who will not connect to the grid when an opportunity arises and continue to use their SSHSs only;
4. Those who already are grid-connected at the time of adopting a SSHS and continue to use it; and
5. Those who are already grid-connected at the time of adopting a SSHS and choose to discontinue using the grid, switching to SSHS only.

Different motivations drive decisions regarding grid connection. Having all energy needs met, being able to plug in appliances other than just those offered by the provider and paying less for electricity, with the belief that grid electricity is cheaper, are the top ones among SSHS users who aspire to get connected to the grid in the future. Continued satisfaction with the services provided and with the functioning of the system are the factors likely to determine the decisions of those who currently either do not want to get a connection to the grid network or are undecided about it.

Chapter 6 Discussion

The discussion chapter brings together findings from the contextual and personal domains chapters, highlighting the interactions between them. It jointly discusses implications of the findings thus addressing the research questions i – vii. The chapter is split into four sections: section 6.1 focuses on how HHs make decision regarding energy access and how energy is used among SSHSs adopters; section 6.2 discusses how energy is used at HH level post SSHS adoption; section 6.3 follows on, looking at energy needs and aspirations, and how those might differ across various groups. Section 6.4 concludes the discussion, extracting key learnings of the study which can guide the process of scaling up off-grid energy access in Rwanda and beyond, stressing the importance of understanding the end-users.

6.1 Accessing energy

There are several factors which influence and shape decisions of rural HHs to adopt off-grid solar energy, such as good quality lighting, mobile phone charging, and improved comfort and well-being, as well as socialising with friends and family in a bright environment. There is also an expectation to reduce expenditure on other sources of lighting, mostly candles, kerosene for lanterns and batteries for torches, and less frequently the grid, and costs required for phone charging (the actual cost and the often-incurred travel cost). These factors can broadly be categorised as internal in the sense that they emerge and are shaped by individuals and within the HH domain: the everyday experiences, performed activities, attitudes and aspirations, and capabilities. Linked to attitudes are perceptions of energy sources in use and the recognition of advantages certain sources have over others, e.g. no smoke in SSHS vs harmful smoke in candles and kerosene lanterns, bright light vs dim light, or payment in cash (plus travel time and cost) vs mobile money payment between the same two. Spouse's positive perception of off-grid solar systems can also impact on decisions taken in the HH, which points to the need for understanding the often complex intra-household dynamics and power relations between spouses and other HH members, also in regards to energy access and use (Horta et al., 2014). Related to capabilities is the question of affordability which plays an important role among all HHs, whether more or less well-off, and regardless of what sources they have been using so far. According to IEA et al., (2018: 17) “[a]ffordability is potentially an issue not only for countries working toward universal access but also for countries that have already achieved it. Estimates suggest that, even in countries with universal access, affordability concerns affect about 30% of the population; in countries working toward universal access, affordability affects 57% of those who already have access.“ As has been shown in this study, HHs as diverse as wealthy, grid-connected and supplementing their lighting with battery-powered torches, and poor ones, relying on candles for lighting, both struggled to keep up with the cost of those fuels. Harrison & Adams (2017) speak of affordability as "[…] subjective, dependent on multiple factors and influenced by both internal (to the person) and external (of the environment) elements. It will be affected by price but is also determined by someone’s available resources, their prioritisation for spending, and their perceived value of a product or service over its lifetime" (p. 7). Section 5.3.5 has offered evidence that HHs prioritise lighting fuels in their regular expenses prior to SSHS adoption and subsequently prioritise the system payment once they have it. System payments are in some cases supported by income generated through the system itself. As a result, SSHSs can also boost capabilities within the HH by not only impacting on the physical well-being through improved comfort but also through contributing to generating financial resources. If saving behaviour is developed or improved after the adoption of a SSHS, other resources, such as cattle or other goods, are purchased, further contributing to the enhancement of economic prosperity. However, although such development of a saving behaviour has been reported in this study, the requirement for regular payments in order to continue receiving service and not get switched off can also create stresses on a HH’s budget, particularly at times of unpredictable external shocks which may demand prioritisation, including financial priority (such events could be illness or death in the family), or may cause financial setback which means resources otherwise put towards needs such as electricity have to be cut (those could include poor harvest, property damage due to a landslide or other natural hazard, etc.). Poorer HHs are more vulnerable and such unpredictable shocks often result in system payments being deprioritised, leading to switch offs, and ultimately defaults and repossessions. The question of customer defaults requires more research as it will be critical for building an understanding of why they happen and how they can be prevented, something this study has not explored in detail but only superficially as defaults fell outside of its scope.

Value for money of SHSs is overall perceived as good, however, a high proportion of community members in areas where SSHSs have already been deployed perceive them as expensive while at the same time seeing them as desirable. Therefore, affordability remains a challenge which could be addressed by further price reductions as technologies develop and become more efficient, as has been the trend in the market of off-grid solar systems over the last decade; well-tailored business models which recognise the limited resource settings, such as PAYG models, also have the potential to address this challenge. More effective awareness raising among unelectrified HHs who may be unaware of the full set of benefits offered by a SHS and unable to make well-informed decisions about their energy access choices, with which existing frameworks such as *imihigo* and *umuganda* in Rwanda can assist, will continue to play an important role. Community buy-in and support will therefore be a critical component of successful electrification schemes, not only for shared energy services (such as mini-grids), but also for standalone solutions. The role of the community and its members' attitudes can either help or obstruct the spread of off-grid energy access technologies and thus fall under the contextual domain, and more specifically the external conditions where, along with policies and other external conditions, they can make up an either favourable or hostile environment for the deployment of such technologies. The risk of them being seen as exclusive due to cost which may still be prohibitive for the very poor HHs can be mitigated by subsidy schemes, MFIs and other credit options (e.g. SACCOs) channelled towards electrification.

Affordability connects both the internal and external factors, which are the other kind of factors driving motivations for SSHS adoption. They are contained predominantly under the shared contextual domain and include availability of energy access solutions which for SHSs means the presence of providers of such systems in any given area, dictated by the policy and regulatory environment which will enable the market of off-grid solutions, as has been seen in the case of Rwanda, other East African nations or South-East Asian countries. The higher the availability, the higher the exposure to alternatives such as SSHSs which results in higher levels of awareness. Raising awareness can be enhanced by off-grid solar providers via organising marketing events locally, radio advertisements and other marketing strategies, which have been successful in reaching a relatively high number of those who decided to switch to a SSHS, or add it to the existing energy mix in the HH. Social networks build spaces in communities where word of mouth or exposure to a SSHS can occur. Seeing an off-grid solar system at a friend's or family member's house has been shown to be an effective and highly motivational way through which awareness of SSHSs can be raised and their benefits experienced first-hand. A first-hand experience or a positive shared peer experience can also build trust among potential future adopters. A negative experience of others can, on the other hand, be detrimental to the adoption of SHSs and hinder electrification efforts (same applies to the adoption of other solutions, including the grid). Men more often than women have such exposure which stems from the traditional gender roles, still prevalent in rural areas, namely women as homemakers or involved in productive activities from home, and men as breadwinners, engaged in productive income generation outside of home. As men move around more, speak to more people outside of their immediate neighbourhood and travel longer distances than women (whose main reasons to travel more significant distances are typically associated with the fetching of water, lighting fuels, food and other HH necessities, as well as phone charging), the likelihood of getting introduced to off-grid solar energy solutions rises. Other strategies include employing Sales Agents who can reach different designated areas, including the more remote ones. The challenge identified in this research points to Sales Agents targeting HHs which are less likely to be poor or, in other words, the better-off HHs which can be seen as more likely to be able to afford a SSHS, even though HHs with higher probability of living under the poverty line also adopt off-grid solar solutions to alleviate expenses on other lighting sources. Such discriminatory approach to sales might dwindle opportunities for poorer HHs to learn about solutions such as SSHSs and inhibit their socio-economic development as the chance to even consider and assess their ability or willingness to adopt such solutions themselves is more limited than in the case of more well-to-do HHs. Awareness raising is additionally boosted through the support of national and local administration, such as has been seen in Rwanda with the REC lead by the government and trickling down to local networks through events and information sharing. Campaigns where government's strong and visible support for off-grid solar solutions for energy access has been propagated are an important vehicle for trust-building in Rwanda. By involving local stakeholders, predominantly in rural areas, the government have not only reached areas where the grid does not currently extend to but have also reassured local leaders that the newly-appearing technologies such as SSHSs have been embraced by the government and incorporated into the national energy access strategy. Local leaders can then, in turn, pass on information and build trust for off-grid solutions in their respective communities. For example, community spaces like *umuganda* have been shown to offer opportunities for local promotion and awareness raising around electrification and beyond. Involving local leaders in trust-building towards new technologies and solutions, not only for energy but other decentralised services, have been discussed widely within the academic community, particularly in among the 'diffusion of innovation' research community (Rogers & Everett, 1983; Rogers et al., 2005; Karakaya & Sriwannawit, 2015), including studies in Rwanda and East Africa more broadly (e.g. Barry et al., 2011; Hansen et al., 2015; Tigabu et al., 2017; Kebede & Mitsufuji, 2017). However, only a very small proportion of this study's participants declared learning about SSHSs in a cell meeting, which indicates a gap and a possibility for utilising such existing social structures to a greater extent in the future. The potential of the *imihigo* framework for extending access in rural areas has also been identified as effective but underutilised at present. Smith & High (2017) and the Special Issue research introduced in their paper, stress the "[…] significance of government interests and public policy for shaping people's experiences of and ethical judgements about energy" (p. 1). Edomah et al. (2017) have also discussed the influences of institutions, and the direct and indirect ways in which policies and political systems impact on the supply of energy infrastructure, and Ulsrud et al. (2018) have acknowledged the importance of a supportive regulatory environment for the success of rural electrification. This kind of impact has been seen in the course of this research and, as an external factor, contained within the contextual domain explored in this study, drives what Tam et al. (2014) call the 4As framework for successful adoption of innovations, originally for agricultural solutions yet equally well applicable to those focusing on energy access, namely affordability, awareness, advantage and accessibility, which have been discussed above, and which cross-cut between the personal and contextual domains, and influence ways in which HHs make choices about energy. Along with other factors discussed in this section, they shape the external conditions, experiences and attitudes, and in an interactive way, by impacting on one another and causing shifts and changes both within the HH (at the individual level) and outside of it (at the shared level), create complex spaces where issues of energy exist, influence HHs and are influenced by them. This reflects the socio-technical transitions perspective which acknowledges those complexities, in the words of Geels et al. (2018: 24) who state that "[…] energy services […] co-evolve with associated technologies, institutions, skills, knowledge and behaviours to create broader 'sociotechnical systems'. These systems are termed 'sociotechnical' since they involve multiple, interlinked social and technical elements, such as technologies, markets, industries, policies, infrastructures, user practices and societal discourses. […] a transitions perspective acknowledges specificities of the kinds of change processes involved." These complex processes will further be discussed in the following sections.

6.2 Energy use

Energy in the HHs is used predominantly for lighting, mobile phone charging, powering radios and TVs, cooking and ironing. After adopting a SSHS, there is a considerable decrease in the use of candles, kerosene and batteries for torches, however, the use of fire wood and charcoal remain unchanged as cooking (and ironing which uses charcoal) is not supported by the system and HHs continue to utilise multiple fuels simultaneously. Unlike in some countries where cultural factors play an important role for cooking fuel selection, e.g. in Nigeria (Ifegbesan et al., 2016; Akintan et al., 2018), such factors have not been observed as significant. Instead, availability and getting them for very little or for free tends to drive the choice of cooking fuels. A small proportion of study participants have expressed interest in solar or other improved cook stoves which also points to an awakening of users seeking better, cleaner and more efficient alternatives to firewood and charcoal. Previously used lighting sources are resorted to at times when the system gets switched off or malfunctions, or in HHs where the number of available lights (i.e. light bulbs) is not sufficient and additional lighting sources are needed. These energy practices support the idea of energy stacking or, as coined by Harrison & Adams (2017) and Power for All (2017), an energy staircase whereby HHs continue to use certain traditional energy fuels even as they adopt more modern ones. They also undermine the idea of an energy ladder which would suggest move from one fuel to another and only using one rather than multiple ones.

Electricity provided by SSHSs is used dynamically by HHs with different system types and has not been seen to increase in a linear manner neither according to length of time, nor according to the number of appliances owned. It has been observed that HHs adopting SSHSs more recently (from the time of data collection) got systems with a lower number of appliances, on average, as opposed to those who had adopted their systems over 6 months or 1 year ago. As much as more research is needed to understand this trend of falling appliance sales, one factor which coincided with the start of it was a change in the business model and the system packages offered to customers. How SSHSs are marketed, the kind of appliance packages available to them might therefore play an important role in off-grid solar systems adoption more broadly (whether SSHSs, solar mini-grids, or other). What is more, users in Group 3, despite having few available appliances used with their SSHSs, have been found to consume more system power, on average, than those in the other two Groups and be more likely to use their SSHSs for income generation, thus also maximising the value for money of their systems. Furthermore, there has been no upward movement on the 'solar energy ladder' across all three Groups. Only one out of 265 interviewed end-users upgraded their system by adding an additional appliance. Only 12% of survey respondents and 3 PPW participants were actively and directly using their systems for income generation, although wider impacts on productivity through extended light hours have been observed among most study participants. These findings challenge some of the ideas in the energy access debate (section 2.3), most importantly that over time HHs will have to upgrade to bigger/higher capacity systems of energy provision as they will incrementally use more power by adding more appliances or by setting up businesses. Expressed needs and aspirations related to energy access will be discussed in the following section, however, this study indicates that not all HHs gaining energy access through off-grid solutions will require increased power supply in the future as not all of them will start income-generating activities from home or continue adding appliances, of which ownership is currently low and does not appear to grow at a fast pace. Consumption levels at present, being low and non-exhaustive of the capacity of an average 50W SHS, also leave room for potential future upgrades as appliances become more accessible, affordable and expand in their range. They also point to a market opportunity for smaller systems which can only support the very basic and most commonly purchased appliances, contradicting the argument that individual, stand-alone energy systems are suboptimal from the service and price point of view, as expressed by Chattopadhyay et al. (2015). The dynamic, non-linear energy use demonstrated in this study supports the idea that, as argued by Smith & High (2017: 1), "[…] multiple conflicting understandings of energy animate how people engage it in their everyday lives and work." HHs and, most importantly, HH members who are the actors engaging in energy use daily, do it differently depending on their needs, aspirations, personal circumstances, capabilities, practices and other internal and external factors which drive energy use. While some might be driven by economic needs and aspirations, others access energy solely to improve their well-being, in all its different dimensions, with social or socio-cultural drivers playing a key role.

The examination of energy use among SSHS adopters through the lens of social practices (section 5.1.3.2) in like manner shows its dynamism. Practice shifts are driven by the available appliances and therefore the available energy services enabled by energy carriers (i.e. the household energy systems or the systems of provision) while at the same time those energy systems are shaped by users' behaviour, including the very practical side of how energy devices and services are used in the HH. Examples include the use of light switches with the need of having them distributed across different rooms rather than centralised in one place or charging several phones at the same time which requires more than one USB port. Those behaviours and practices dictate how energy is used and can in turn inform the design of energy systems. Existing (prior to adoption) and newly arising (post-adoption) users' needs and aspirations can then further inform the broader design of HH energy systems, including new devices and services which have been expressed as lacking (e.g. insufficient number of light bulbs) or desirable (e.g. a shaver to shave family members' hair or start a barber shop). These dynamic interactions between the HH energy systems, which lie at the heart of the framework applied in this study, and the personal domain of energy use, support the premise of a co-construction of user practices and energy technologies (Geels et al., 2018; Oudshoorn & Pinch, 2003), and Shove's and Walker's, as well as Spaargaren's concept of social practices in which they deem consumer behaviour to be enabled, constrained and contextualised by the energy systems (Shove & Walker, 2010). What system types (or packages, i.e. systems and accompanying appliances) are adopted is guided by their availability (driven by external factors) and the HH's capabilities, which then shapes the realities and practices of HH members depending on what appliances and services they get access to. In a HH using a system with a TV different practices might develop (e.g. children watching movies), change (e.g. watching news, a football game etc. at home rather than at a bar or at a friend's place) or disappear altogether (e.g. no longer listening to a radio for news) than in a HH without a TV.

This study has also observed energy use to have a gender dimension. This finding is in line with Dutta et al. (2017) and Fingleton-Smith (2018) who argue that women are the primary beneficiaries and primary users of energy, while at the same time being the ones who have less agency in making energy-related decisions due to traditional gender roles which create the mismatch between the people who benefit the most from modern energy technologies in the HH and those who acquire them, i.e. men in the dominant economic position. As cooking is not currently supported by SSHSs (or any other SHSs), women continue to be exposed to harmful smoke on a daily basis as firewood and, less frequently, charcoal remain the most common cooking fuels which HHs rely on, due to their affordability and availability. The continued use of multiple fuels further supports the energy stacking, or energy staircase, behaviour, and might undermine the benefits of adopting modern energy solutions such as SSHSs, as has been argued by Tait (2017) through persisting cooking practices which remain unchanged post SSHS adoption. This points to the need of more actively engaging women in energy access discussions, decisions, policy-making, and business model design, which has been advocated by a number of researchers and organisations in the recent years (Dutta et al., 2017; Aharonian et al., 2017; de Groot et al., 2017; Ryan, 2014; Pachauri & Rao, 2013) as questions around energy equity and equality (Sovacool et al., 2017; Tomei & Gent, 2015; Bazilian et al., 2014), and energy justice (Kumar, 2018; Jenkins et al., 2018; Bouzarovski & Simcock, 2017), including the gender perspective (e.g. Ngum, 2016; ESMAP, 2018; SE4All, 2018), have started to become more prominent. Even though this study has not examined questions around justice in energy access, and the gender power dynamics which may contribute to the hindering of women's participation and shaping of household energy systems, despite having an active part in their uses, it is recommended that more research be done on the gender aspects of energy access. This will also allow a more appropriate design of such systems in the future by benefitting from an improved understanding of women's realities in and outside of the HH context, as well as their needs and aspirations, which will be discussed in the following section.

Use of SSHSs for energy access has been shown to create numerous socio-economic impacts, with women and children experiencing them and benefitting from them the most. Access to information and entertainment through radios and TVs is highly valued not only at an individual level, but also from the community's point of view. A HH with access to a TV is regarded as having a higher social status than one without one, similarly as a HH with electricity is perceived as 'more developed' than one without access. Households with a reliable source of lighting and a TV have also been seen to turn into places and spaces of community gatherings, causing a shift in community social practices such as gatherings in public spaces or local bars. Thus, improved energy access at a HH level can be felt beyond the constraints of a HH, with changes in the personal and individual domains impacting on the contextual and shared domains. As certain energy-based services get replaced by SHSs (e.g. phone charging at charging stations), the composition of local service landscapes also gets affected, potentially pushing redundant services out and calling for new ones which might be required to support the off-grid energy value chain.

Time savings are nearly ubiquitous among study participants. Rinkinen et al. (2015: 13) content that "[…] time [is] either a resource on which practices depend or something that is made by and through the recurrent enactment of different practices." In this study, time is a resource that is made through the changing practices resulting from the adoption of a modern energy source which can now support needs which would otherwise have to be satisfied outside of one's home and require time to get accomplished, such as the above-mentioned mobile phone charging. That extra time can then translate into the development of new practices or reshuffling of the existing ones (at both HH and community level). Even though time savings are evident in the findings, financial savings are not as straightforward and are generally more challenging to estimate. Performing actual calculations of what used to be spent on energy, and what is spent now with a SSHS is uncommon. However, despite that, there is a noticeable sense of saving among study participants who, even if they do not actually save money as a result of adopting an off-grid solar system, have been observed to develop or improve their saving behaviour so that they can pay for the system on a regular basis. Zollmann et al. (2017) have found a similar saving behaviour in their study of the value of PAYG solar for end-users. Economic impacts of energy access have been of particular interest in the international development community with a lot of expectations placed on extending energy access to rural HHs, which tend to be poorer than their urban counterparts in low-income countries. It is expected that with access to energy, and particularly with the adoption of improved, modern energy sources, HHs will embark on an upward movement on the economic ladder. However, even though small income generation is made possible and more productive hours are facilitated, income-generating activities post system adoption are not prevalent and the uptake of appliances remains low, meaning that HHs are hesitant to invest in additional appliances which could potentially enable more or other income generating activities. The main barrier is affordability as well as terms of upgrades. Instances of HHs willing to add on appliances but unable to do so have been observed, which can be seen as a hindrance in the upward move on the solar energy ladder to unlock a wider range of productive use opportunities. Yet economic gain expectations should also be considered with caution. Lenz et al. (2017) have conducted a study on the impacts of Rwanda's electricity roll-out programme which saw the number of grid connections increase yet power consumption and appliance uptake remained low, and the impact on classical poverty indicators, including income, was not significant. Similarly, in their study of grid extensions in Kenya, Lee et al. (2017) observed low demand for grid connections, and limited socio-economic impacts on HHs which connected to the grid network, even after a considerable amount of time (18 months). Mini-grid providers in East African countries have struggled with similar challenges, namely low power consumption and low appliance uptake. Although SSHSs are rightly said to be unable to fully substitute a grid connection due to their capped capacity (e.g. Lee et al., 2016), by the nature of the technology they rely on, low levels of power consumption due to limited available appliances, and no or little increase in the consumption trend over time have been observed across all different energy technologies of various Tiers of energy access they offer, according to the ESMAP Multi-Tier Energy Access Framework.

6.3 Needs and aspirations

Despite the relatively low observed levels of consumption and practically no upward movement on the solar appliance ladder, and the high levels of satisfaction with the amount of electricity provided by the SSHS, there has been a recurrent expressed need for a higher capacity/stronger system battery. Data from the SMART Solar platform monitoring systems performance and consumption levels show that users consume on average less than what the system can provide. However, system appliances are used throughout the day with the highest utilisation of most available appliances concentrated in evening times. At the same time, there is a noticeable disconnect between the best practice of SSHS use as recommended by the provider and what the end-users' understanding is about how to use the system in the most optimal way. Although adopters generally find their SSHSs easy to operate, there has been an expressed need for more training to learn more about how to use the system properly. As knowledge of solar energy is poor among those who adopt such technologies, due to their novelty and relatively low levels of education, offering adequate training could play an important role in ensuring benefits of energy services provided by SSHSs are maximised and needs are met. Lessons from sustainability transitions research community can be applied, even if the scale and the nature of energy systems might be different (traditionally focus on grid-connected HHs vs decentralised off-grid SHSs). As argued by Røpke (2009: 2490), transitions to sustainable consumption require "[…] collective efforts supported by research into the co-evolution of domestic practices, systems of provision [here: household energy systems], supply chains and production." In this case study, the challenge is not how to make end-users consume less energy or consume it more responsibly, as is applicable in the context of high-income countries, but rather hot to make them use the available energy more efficiently to satisfy current needs with currently owned appliances, as well as any future appliances which might address outstanding needs or help satisfy HHs' aspirations. Customer training, the ability to remotely configure users' systems to best adjust to their profile of energy use behaviour, as discussed in Bisaga et al. (2017), together with an in-depth understanding of energy-related practices (and habits) motivated by the core concerns of everyday life have the potential to produce “competent practitioners” (Røpke, 2009).

Sufficient lighting and phone charging are the most critical needs in terms of system appliances. These needs are the most basic among adopters of SHSs (whether SSHSs or other) and, if they are fully met, impacts of such systems will be the most significant as there will be no further need to resort to lighting fuels previously relied on (such as candles or kerosene) to complement the outstanding needs (e.g. lighting in rooms where the system does not reach due to the insufficient number of light bulbs), or paid and/or time-consuming phone charging services sources outside of one’s home. Well-functioning energy devices securing reliable energy services are another key need of SSHS adopters. Malfunctioning or altogether non-functioning devices cause dissatisfaction and can lead to repossessions as customers cease their payments. Additionally, they can result in a negative word of mouth effect where dissatisfied HHs will discourage others around them from adopting similar systems, potentially hindering electrification efforts at a community level. After-sales support services play an important role in customer retention. Over time, as systems are used, and the likelihood of technical issues increases, reliable and end-user-friendly customer care services will be needed to ensure not only continued use of the systems without unnecessary delays (e.g. time required to fix a faulty system), but also to retain customers for the long run.

Not all SSHS adopters aspire to eventually get connected to the grid. The aspirational thinking about energy access concerns the expansion of energy services more than the desire to connect to the grid per se. Those who are not satisfied with the amount of electricity provided with the system and do not believe it can support their needs in the future will choose to opt for grid access. However, others who believe their needs can be supported by solutions such as SSHSs will choose to rely on them for energy access as long as they continue to receive good quality, reliable and responsive in times of problems energy services. Additionally, even if the grid becomes available, issues around affordability of connections, reliability and safety of use will also play a role in decision-making. End-users’ perceptions of permanency of solar systems goes against the argument that such solutions are only temporary as they cannot support more energy demanding services beyond the relatively basic ones currently offered by

SHSs (Bazilian & Pielke, 2013). This is further supported by what has been discussed in the previous section, namely that not all HHs will require unlimited energy provision levels for high energy consumption appliances, as not all of them aim to start a business or have energy needs and/or aspirations which go beyond what a SHS (incl. SSHS) can support or will otherwise be able to support with the growing market of off-grid solar, super-efficient (DC) appliances. Additional appliances beyond lights and phone chargers often remain aspirational for low-income, rural households. Affordability and availability of those appliances, in addition to their compatibility with off-grid solar systems, which run on DC power, remain a barrier. To date, the dominant model is that system providers also offer a range of appliances which the customers can plug in to their systems and cross-use of other appliances, which might or might not be compatible with the SSHS, is discouraged. However, that also means that customers are mostly presented with options to add on new appliances and pay them off over a period of time (e.g. 12 or 36 months), which increases the monthly (or daily/weekly etc.) payment, but also means that the total price of the appliance is higher than what it would be if it could be purchased off-the-shelf. Opening up the market of off-grid solar appliances available on a direct-sale basis (a one-off payment rather than a payment split into instalments) could therefore contribute to increased appliance uptake and thus increase use of energy, meeting more end-users' needs and fulfilling their aspirations which might currently be hindered by the dominant models of provision. Those will not only be driven by shifting practices which might result in an emergence of new ones requiring different energy services (and therefore different energy devices), but also by the willingness of HHs at a collective level and HH members at an individual level to "climb the development ladder", as study participants framed it, and, in the spirit of *imihigo* or similar frameworks elsewhere, achieve more and secure a better life. Recognising user-perceived value of energy benefits is an aspect of business and service model design which can inform offerings better-tailored to the end-user (Hirmer & Guthrie, 2017).

However, to understand the end-user also means acknowledging both the shared and the individual domain of everyday life which enables to distinguish between the needs of individual HH members which can either overlap or differ. As has been seen in earlier sections, women have been found to be the primary beneficiaries of energy but remain underrepresented in the decision-making on and ownership of energy systems in the HH. Because of distinct gender roles, men's and women's needs and aspirations vary, even if both men and women can recognise and support each other's needs and aspirations. Cooking is currently one of the biggest challenges of energy aspirations which is not supported by off-grid solar solutions due to being particularly demanding in terms of power consumption. Designing solar-powered cook stoves, hybrid cook-stoves partly supported by solar power (Zubi et al., 2017), or other cooking solutions which could be included into the service offering of SHSs providers has the potential to greatly alleviate the cooking burden placed on women across rural, peri-urban and often also urban areas of low-income countries. Utilising the relationships built between the providers and the end-users of off-grid solar solutions, and the existing distribution channels established by the service providers, might ease the dissemination and adoption process, particularly where trust and positive experience of services have been formed. This additionally highlights the importance of good quality, affordable, reliable and user-focused services for the retention of customers and for the facilitation of additional future services beyond those currently offered, which can in turn trigger increased uptake of appliances- a win-win scenario for both service providers and end-users. Osiolo (2017) has argued that HHs are willing to pay for improved energy access, including for off-grid solutions such as SSHSs, as long as the services are of high quality and meet their needs. Paying for energy access (whether with or without a SSHS) has also been shown to be prioritised among HHs in this study, including those who are the most likely to be poor. With unsatisfactory experience of energy services by providers such as BBOXX, who guarantee after-sales care for various periods of time (currently anything between 3-10 years), HHs might choose to opt for other similar solutions, such as the generic or counterfeit off-grid solar systems sold on a cash basis which have been entering markets in Rwanda and beyond. However, as they seldom offer after-sales support, which leaves those adopting them on their own in the case of any system issues, the risk of tarnishing the reputation of SHSs increases, thus posing a threat to the sustainability of off-grid solar markets, potentially hindering rates of adoption in areas where they are most needed and can offer the best value-for-money energy access option to unelectrified HHs.

6.4 Scaling up off-grid energy access

Achieving universal electrification by 2030 will require a concerted effort of different stakeholders, and will include a mix of on-grid, mini-grid and off-grid energy access solutions, among them SHSs (World Bank et al., 2017; Shell Foundation, 2017; World Bank, 2014). This research has shown that in order to scale up off-grid solar energy access, it is critical to provide tailored services which address end-users' energy needs and are built on a thorough understanding of what adopters of such solutions rely on prior to choosing stand-alone solar systems, and where the key advantages for switching to modern sources of this kind lie. Learning about the different trends of energy use, which is enabled by remote monitoring of SSHSs (and other similar solutions in the energy sector), can greatly assist with and help design systems which will respond to individual HH's needs and will be invaluable in sizing future systems, in addition to providing remote support and custom system settings based on the energy use patterns. Given the dynamic nature of consumption among SSHSs users, flexibility of energy services will play an important role in meeting the differing needs which exist at the time of system adoption, as well as future needs and aspirations which may go beyond the services offered at the time of customer acquisition. However, scaling up off-grid solar energy access will not only mean acquiring new users, but also scaling up existing ones through the expansion of offered services, i.e. gradually meeting more of their needs and offering potential for meeting aspirations associated with higher tiers of energy access. A wider range of more affordable appliances compatible with SSHSs will be needed to enable new services to be available at a HH level and at a community level, in that they will gain access to energy services more locally.

Affordability, reliability and high quality of energy services and devices, which enable the use of provided services, together with after-sales and maintenance care, are among the main factors that will impact on customer retention and sustained, long-term use of SSHSs. User experience is shaped predominantly by their interactions with energy services and devices and impacts on future decisions regarding either retention of off-grid solar systems or switching to the grid if/when it arrives. Improvements in energy storage will continue to influence the day-to-day use of energy and improve the experience as more power becomes available, supporting accompanying system appliances (i.e. energy devices) for a longer time and opening a possibility to expand the appliance range, thus expanding the available energy services.

Robust business models which accommodate the needs and aspirations of end-users have to address issues of affordability and also flexibility to enable payments which suit the customers who often rely on irregular, seasonal incomes. Recognising women as primary beneficiaries of energy will be of critical importance to ensure appropriate solutions are developed, so that they can truly serve the end-users. Gender mainstreaming in the design and implementation of energy access and increased participation of women in decisions regarding energy services and planning will be necessary to maximise impact and uptake of off-grid solar solutions, such as SSHSs. Additionally, it is important to acknowledge the dynamic and complex nature of energy use, and recognise that energy access is not a linear, stepwise process, but a dynamic one that is more similar to the energy staircase model than the energy ladder one. The concept of a solar energy ladder has also been challenged, with little evidence to support it found in this study.

Existing and new policy frameworks addressing holistic development planning inclusive of energy access are going to continue playing a crucial role in guiding electrification efforts of all different stakeholders within both the personal and the contextual domain where energy decisions are made, energy access shapes the daily reality of the end-users, and perceptions about modern energy technologies are created. Quoting Atieno et al. (2018: 1): "For meaningful improvement to be realised towards meeting the energy SDG by 2030, national and local energy policies should consider the energy technology adoption perception and behaviours of populations currently not having modern energy access. In conclusion, it is of great importance to put into context the specific characteristics of the households as well as user perspectives and how these characteristics and perspectives would affect continuity of usage of the modern energy source adopted."

Taking learnings from this case study and applying them not only to electrification efforts in Rwanda but also to other countries and regions without universal energy access can also help realise such improvements towards SDG7 in particular by demonstrating how low-income HHs access and use energy, and what needs and aspirations exist among those who might not currently possess the ability to utilise energy to maximise its benefits due to the lack of electrical appliances and means to access modern energy services. The very basic energy needs have been seen to be universal across countries and cultures. Energy usage patterns can also be expected to vary only minimally among HHs accessing modern energy for the first time and be dynamic rather than static or linear, with energy stacking present in most countries and across different social strata. Challenges associated with the sustainability of off-grid solar solutions are likewise similar in that there is a need for after-sales services and repairs assistance regardless of where such solutions are deployed. Ensuring there is a follow up post product deployment and developing a positive customer-provider relationship offers the opportunity to improve retention rates of customers and therefore a more economically viable business with a long- rather than short-term relationship between the two. Ensuring gender-conscious approaches are developed and incorporated into the models of provision will additionally enhance the scalability and sustainability of off-grid solar or other energy access systems as women around the world are predominantly the ones benefitting the most from energy services, with this Rwanda case study being another piece of evidence among the existing body of work on gender and energy access. Finally, the external conditions made up by the favourable policies and regulations, as well as socio-cultural frameworks and the inclusion of the community into the electrification efforts can be learnt from or replicated in other countries looking to introduce and/or scale up off-grid energy access.

Chapter 7 Conclusions

7.1 Key findings and contributions

The key findings and contributions to the existing academic body of knowledge on the users of Solar Home Systems stemming from this research are as follows:

In relation to question 1: How is energy accessed and used in the household, pre and post adoption of a SSHS?

- Pre-system adoption, HHs predominantly rely on candles, kerosene lanterns and battery-powered torches for lighting and fire wood for cooking. Other basic energy uses include ironing, access to a radio, and mobile phone charging, which is sourced outside of the house. Energy stacking is a common practice and different energy fuels are used for different applications, with at least 3 or 4 different ones used at any one time (internally at home and externally, at charging stations or other charging points).
- Energy stacking continues post system adoption as cooking remains an outstanding energy need which is currently not supported by SHSs (including SSHSs), and in instances where not enough system lights are available, meaning that not all rooms in the house can be lit up, HHs complement the use of the SSHS with other lighting sources, such as batteries or candles. Energy transitions in HHs follow an energy staircase path rather than an energy ladder.
- HHs of various poverty levels, as well as those living off-grid, on-grid and under the grid adopt solutions such as SSHSs, whether as the main or complementary access to energy, substituting mainly candles, kerosene lanterns and battery-powered torches for lighting, and substituting or complementing grid access which can be unreliable, erratic and which is perceived as unsafe due to the risk of electrocution and power surges.
- HHs choosing to switch to SSHSs do prioritise energy expenditures, both pre and post system adoption. System payments are among the regular monthly expenses and fall within the top three priority ones, regardless of their poverty level (i.e. all three groups examined in this study: low likelihood of being poor,

intermediate likelihood of being poor, and high likelihood of being poor, place energy access expenses within the top three monthly expense priorities).

- Every HH member relies on energy for lighting and other basic services, however, it is the women and children who are the primary users as they spend the most time at home. However, men are the ones who are most commonly in charge of energy related decisions and they are the registered owners of SSHSs considerably more often than women.
- HHs in Northern and Western provinces of Rwanda commonly use the *imihigo* framework and set performance targets on a yearly base, working towards achieving them in the course of a full year (September to September). Energy access is one of the targets although off-grid solar energy option does not appear on the list of energy-related targets in booklets which HHs use to choose their goals. *Imihigo* speak not only to energy access, but also to other needs and aspirations of HHs and their members and have been found to have a potential to boost adoption of off-grid solar energy solutions and promote their benefits, particularly for those not yet electrified and relying on polluting and often expensive sources. Existing community spaces, such as *umuganda*, can be utilised to raise awareness of energy access options such as SSHSs, and the government's facilitation and support of awareness raising campaigns promoting off-grid solar as an alternative way of accessing energy, especially in remote locations where the grid network will not be available for years to comes, is critical to build trust in such new energy technologies.

In relation to question 2: What is end-users' energy behaviour and consumption as tracked by SSHSs and as self-reported? Does it increase over time? And does it depend on the system type (i.e. the set of available appliances)?

- Use of energy is dynamic. Power consumption does not increase in a linear manner over time and with a higher number of appliances. Customers with fewer appliances who use them more, including for income generation, and get the most value for money from the appliances they have included with their system type/package consume the most power.

- Power consumption among SSHSs users is low and averages between 20 and 35 Wh per day. Low consumption levels relate to the low ownership of electrical appliances, with light bulbs, phone chargers and radios being the more common ones.
- Peak hours of consumption are in the evening (between 6pm – 12am), with phone chargers, and radios and TVs (among those HHs who own them), used throughout the day as well.
- There is no observed climb up the solar energy ladder in terms of new appliance acquisition over time and a decreasing trend of appliance acquisition at the point of subscribing to the provider's services among customers adopting SSHSs more recently (<6 months), in this study under a changed business model, than those who had adopted SSHSs a longer time ago (6-12 months, and >12 months).

In relation to question 3: What are the energy needs and aspirations? Do they differ among end-users? And are they met by SSHSs?

- Energy needs of rural HHs in Rwanda are basic in terms of the most-desired appliances, which cover lighting, phone charging, access to information and entertainment (radio, TV, smartphone, laptop), and other daily use appliances, such as shavers and irons. Irons and laptops are not commonly available with SHSs currently offered by existing providers.
- The above appliances link to what end-users need and value the most about having a SSHS in their homes: a reliable source of bright light, which impacts on all different areas of daily life and enhances well-being, particularly of women and children who spend more time at home than the men of the HH and therefore use the system the most; having their mobile phones always charged and not having to pay for charging services; being able to save money by reducing or eliminating expenditure on lighting fuels and phone charging; being able to socialise with family and friends, and cook with more ease in the evening in a well-lit environment; and the feeling of safety and security at night due to outdoor security lights and indoor lights which enable movement around

the house without the risk of injuries, as well as the elimination of indoor fire hazards resulting from discontinued use of candles and kerosene lanterns.

- HHs' needs are partly addressed by SSHS. The very basic needs are met, however, HH could benefit from more of the appliances they already have (more lights to cover all areas of the house and more phone chargers to be able to charge more phones at any one point), and access to other appliances (such as radios, TVs etc.) at affordable prices. Despite aspirations for expanding the range of existing system appliances among study participants, uptake remains very low: among survey respondents only one end-user upgraded by adding a new appliance between September 2016 and 2017.
- Income generation with the use of SSHSs is limited and predominantly utilises mobile phone charging and lights (for lighting businesses and/or extending working hours either at a business place or at home), with TVs less frequently used as a way of attracting customers (e.g. in a bar) or charging people coming to watch TV. Aspirations for future income generation using the system among those who do not currently do so are not universal across all customer groups. Approximately 60% of SSHSs adopters who do not yet generate income with the use of their systems would like to do so in the future. More women than men have expressed interest in future income generation which indicates that women should also be included in the work on productive uses of off-grid solar energy solutions in low-income country settings.
- End-users need and expect good quality, reliable energy services, both in terms of the functioning of the systems (long-lasting battery) and system appliances, and after-sales services, such as maintenance, repairs and customer information provision either in person (at shops/distribution points) or via a call centre. Quality services will be critical to retain customers. Poor experience of energy services can result in customers switching to other providers or to the grid network if and when it becomes available. It can also cause negative attitudes to SHSs or similar solutions as word of mouth remains one of the main channels of raising awareness about off-grid solar energy in rural communities.
- Aspirations for access to the grid network are also not universal, i.e. not all adopters of SSHSs who have not yet been connected to the grid aspire to be connected in the future. A smaller proportion of HLP group customers have

such aspirations as compared to the other two groups (IL and LLP). As long as energy services provided by BBOXX are satisfactory, the likelihood of customers switching to the grid and abandoning their systems remains low. Overall, there are three categories of customers when it comes to grid aspirations: those who will switch from SSHSs to the grid when it becomes available and discontinue using SSHSs; those who will not connect to the gird even when it arrives; and those who will connect but will retain their SSHSs.

- Cooking remains a critical energy access need currently unsupported by SSHSs or similar solutions. Future developments in the off-grid solar energy sector should focus on finding either fully solar- or solar-hybrid supported solutions for improved cooking.

In relation to question 4: What are the key socio-economic impacts as experienced by the users of SSHSs?

- Impacts on those adopting SSHSs for energy access are significant, particularly on women and children, and encompass improved comfort and well-being due to indoor smoke reduction, extension of productive/study/light hours later into the evening, improved safety and security, and the ability to always be reachable because of having ready access to mobile phone charging.
- A considerable proportion of end-users feel they make financial savings as a result of switching to a SSHS as they save up not only on lighting fuels (candles, kerosene and/or batteries) but also on phone charging and transport costs for getting fuels and charging services. Not all study participants calculated the actual savings. However, there was a strong feeling of making savings, also and most importantly in terms of learning how to save/put money aside every month. This has allowed some customers to improve their livelihoods or start relatively small income-generating activities, e.g. mobile phone charging for neighbours, friends or other community members, or by buying a cow and selling milk of fertiliser generated from the cow's waste. Other income-generation impacts include using system's lights to extend working hours into the evening and light us business places past early evening.

- Time savings and enhanced time flexibility due to the ability to reshuffle daytime activities (work, chores etc.) and utilise the night time hours, as well as due to the elimination of the time spent on fetching lighting fuels and getting mobile phones charged, are considerable and mean more time for social and productive (in-HH or outside of HH) activities. This relates to the shifting practices post SSHS adoption: practices are reshuffled in space and time, allowing for more flexible daily schedules and for more activities to be performed, or for activities to be performed with a greater level of ease (e.g. washing up is easier in the evening hours with a bright light on).
- Women and children are the main beneficiaries of the systems and the services they offer as they spend the most time at home.
- Reported study time for children extends by an average of 2 hours per day. Children also benefit from the light provided by the system in other ways: by having a better study environment, without smoke; by having a safer play environment; and by having access to information and entertainment at home. The latter two also mean that children are less likely to wander away from home in the evening post system adoption.
- Cooking remains a challenge and can compromise the benefits achieved from eliminating candle and kerosene smoke as majority of study participants continue to use fire wood or charcoal for cooking, due to availability and affordability. Women are the most impacted being traditionally the ones in charge of cooking.
- Switch-offs and system breakdowns can also compromise the positive impacts of having a SSHS by forcing HHs to go back to using candles, kerosene and/or battery-powered torches, as well as getting phones charged externally. Insufficient number of lights can also cause the need to supplement the lighting of one’s house with traditional lighting fuels, which can negate the positive impacts such as the elimination of smoke and/or financial savings.
- Inflexible payment methods are challenging for customers who tend to have irregular incomes and require the ability to pay their systems off in a flexible manner, i.e. allowing higher payments (or instalments) when cash is available and no/small payments when cash is scarce.

- Affordability remains a challenge and manifests itself in the low uptake of additional appliances (despite aspirations for such appliances being high) over time, and the number of customers who default on their payments.

And finally

In relation to question 5: How can improved understanding of energy use and customers' needs and aspirations, as well as key impact points, help provide adequate energy services and scale up off-grid solar energy access, in Rwanda and beyond?

- By guiding product and service design of private providers of off-grid solar energy solutions: building good quality, reliable energy services which are appreciative of and serve customers' needs is critical for ensuring customer retention and long-term use of SSHS among adopters. Realising what customers need and aspire to, and what challenges they face in their lives can also guide future strategy and business models which can be better tailored to the customers who adopt solutions such as SSHSs.
- By enabling tailoring systems, and more specifically systems' capacity, to the levels of power consumption which is seen among system adopters. As the range of used appliances remains low, system parameters can be adjusted to relatively low levels of power consumption which is lower throughout the day and peaks in the evening hours. To that end, remote monitoring and the ability to remotely monitor systems' performance, such as is made possible through the SMART Solar platform, can be helpful.
- By improving understanding of the socio-cultural aspects of energy use which can also enable both the private sector and the public sector to recognise dimensions such as gender dynamics and the importance of including women as the main beneficiaries and users of energy in energy planning, project and programme design, and product and business model design.
- By identifying gaps in available services and opportunities for maximising positive impacts and eliminating or alleviating the negative ones.
- By recognising the impacts energy access has on the wider community in addition to individual HHs and their members, as well as the role of the community itself in the electrification efforts: their buy-in and awareness of energy access options will be crucial to build an environment where a mix of

solutions can be deployed and co-exist. Affordability and inclusiveness of energy access technologies being among the top needs for both HHs and wider communities to become electrified will have to be addressed through a range of product and service offerings covering a diverse set of energy needs and aspirations, and subsidy schemes which will enable the poorest HHs and communities to access energy in an equitable way.

This study has also contributed to the limited body of research on the use of Social Practice Theories for understanding energy use in rural communities in low-income country settings and has made a contribution to the (solar) energy ladder argument which has been a debated concept in the energy access literature to date. It has further contributed to recognising ways in which existing cultural and policy frameworks, such as *imihigo*, can help raise awareness of off-grid solar energy solutions and increase uptake thereof.

7.2 Implications for different stakeholders

Implications of this study are wide-ranging and can be categorised into three groups: 1) implications for the private energy sector and for energy practitioners; 2) implications for the public energy sector; and 3) implications for academia. They are elaborated below.

<u>Implications for the private energy sector and for energy practitioners:</u>

End-user focussed energy product and service design are critical to ensure that they meet the needs of HHs and individual members, and that they fit in well with the HH environment. Recognising the human side of energy use with both the contextual and the personal domain offers valuable insights into the lived experiences of end-users, their daily lives and their routines, decision-making processes, and the external factors which play a role in shaping those realities, such as policies, socio-cultural frameworks and local or national initiatives which might drive customer behaviour.

Learning from both quantitative and qualitative data is important to get a better understanding of the end-users. Different data streams can reveal different aspects of energy use and are equally necessary for designing comprehensive solutions which encompass all needs and speak to the aspirations of those living off the grid.

Off-grid solar systems, such as SSHSs, should target not only rural HHs but also those in peri-urban and urban areas where grid and off-grid energy access are not mutually exclusive bur rather complementary.

Women should be actively included in the design and planning of energy access programmes and energy services as they are the primary users and beneficiaries of those very services.

There is scope to apply practical learnings from studies of this nature into project planning and implementation, as well as the above-mentioned product and service design. As in-depth understanding of the how's, why's and when's of energy access can help ensure solutions such as SSHSs are seen as long-term energy access options.

Private sector and practitioners working on energy access should not only recognise the importance of the gender dimension in energy access planning, but also help inform the public sector.

Implications for the public energy sector:

Off-grid solar energy solutions have been shown to satisfy most energy needs of HHs which are currently living off the grid or with unreliable grid services and have the potential to fill in the vast electrification gap that currently exists. They should therefore be included in energy policy and treated as complementary energy access solutions which can serve unelectrified HHs whose energy needs can be supported by these kinds of technologies. It should also be recognised that not all HHs will connect to the grid as and when it arrives but rather, some will continue using off-grid solar energy only, others will use both on- and off-grid energy, while others will switch to the grid.

End-users' needs and aspirations, as well as energy use behaviour prior to switching to modern energy sources, should be recognised for the tailoring of energy access planning so that best value-for-money and most suitable solutions are made available, affordable and accessible to the energy poor.

Existing policy frameworks can be used to maximise efforts related to energy access and raising awareness of alternative energy access solutions such as SHSs. The example of *imihigo,* as well as other HGSs, demonstrate potential to be effective channels for scaling up energy access and learnings from them can be applied in other places where similar frameworks exist or where there is an opportunity to design new ones which could include energy access components. The Rwanda case study can be used as an example for such developments in other countries and regions.

Gender mainstreaming in energy policy, planning and implementation is critical in order to ensure that all end-users' needs are met and that interventions are not informed by voices biased towards those who might be in charge of energy decisions at a HH level but not primary users and beneficiaries of energy services.

Energy access is a piece of the development puzzle which by itself has a limited ability to address economic well-being as not all HHs will start generating income off of their energy services once they become available.

Implications for academia:

Energy access and energy transitions to modern energy sources are complex processes and require mixed research methods to fully understand the scope of the challenge, as well as issues around energy use and impacts, going beyond quantitative data only, which reveals a part of the reality of energy use, whether among rural, peri-urban or urban HHs.

Application of Social Practice Theories to understand energy use among adopters of off-grid solar energy technologies in low-income countries demonstrates the scope of changes that occur in a HH after gaining access to a modern energy source in a way that impact evaluation only cannot provide. It offers a way of gaining a deeper understanding of the daily energy use realities and the practice shifts, disappearances and emergences which stem from having access to improved energy in the HH. So far, the SPT have been sparsely utilised in the context of energy transitions among off-grid, unelectrified populations and present an opportunity to be more widely applied in order to build the limited knowledge of the sociology of energy use in low-income countries working towards universal electrification, rather than transitioning from unsustainable to sustainable energy technologies and uses.

Participatory photography is a valuable qualitative data collection technique which offers broad and deep insights into the energy use at a HH level. It complements other qualitative data collection tools and through the photography aspect of data generation, expands and enriches research datasets by adding a visual component to written and numeric data. It is more personal in nature than information shared through interviews, surveys or FGs, and can reveal important areas of personal and collective realities which are difficult to capture through the more traditional tools.

And finally:

There is a need for a concerted effort of all stakeholders in addressing the energy access gap. Private sector, public sector, donor community, academic community, energy practitioners and other local, national and international stakeholders will all play a part in making universal access to energy possible. Learnings from various country case studies can be applied and referred to in order to best suit the local context, to extract best practices and avoid potential mistakes which are not pertinent to the socio-cultural context but can occur under any circumstances and cultural setting.

7.3 Further research recommendations

There is a number of further research recommendations that stem from this study. Among them:

- Further research on the uptake of appliances, what drives it and what business model adjustments might be able to address the issue of affordability. It has been seen that needs and aspirations for more (of the same or new) appliances are there, however, those are not reflected in the limited uptake of new appliances.

- An investigation which would allow to better understand what the key factors are that drive defaults and how they can be addressed, alleviated or prevented, and what measures can be applied to help those HHs at risk of having their systems repossessed.
- Further research on 'practice reversal' post system repossession: what happens to those who default and lose their systems, or give them up due to dissatisfaction with the service or any other reason? Do they simply go back to 'square one', i.e. status quo from before SSHS or do they adopt other off-grid energy solutions?
- Investigation of system usage data (collected via remote system monitoring) in order to understand if and what steps could be taken by both SSHSs users and providers that would make the use of the systems more efficient, thus increasing light hours and meeting as many of customers' needs as possible and for as long as possible. Further investigation of the training on system use is also needed to understand whether better training results in more efficient and prolonged system use.
- Research on if and how women are included in energy access decisions, both in the HH, but also at local and national level. A closer examination of women's aspirations for income-generating uses is recommended as it might help drive increased use of SHSs and similar off-grid energy technologies for productive uses/income generation in rural areas of low-income countries where such uses are the most needed to further contribute to poverty alleviation efforts.
- Research on technology and business model development in order to expand the capacity of SHSs for future energy demand increases and to accommodate more energy-demanding applications, as well as to accommodate for more of the same appliances (e.g. lights, chargers etc.) to be used with the systems while keeping them affordable, even to the poorest of the off-grid and under the grid populations.

7.4 Study limitations

This study has several limitations which have to be acknowledged. The most important limitations identified by the author are as follows:

- This study focuses on investigating only one provider of SHSs (here SSHSs) which poses a limitation in that it does not take into consideration other similar providers and therefore limits itself to understanding customers' experience of a particular provider and service. Even if those are not much different considering similarities in products, services and business models across SHSs providers in Rwanda, there inevitably exists a level of variation and the experience will differ among adopters using different products and services. However, these differences are not considered to be significant enough to deem the results of this study not representative.
- There is a potential bias of customers who participated in the study: even though it was clearly explained to them that the researcher and the RAs were not BBOXX employees, some might have considered them as such and have their answers or discussions shaped by that thinking, particularly because BBOXX regional employees (Shop Managers or Sales Agents) would help arrange FGs and sometimes remain present (particularly in instances where a Sales Agent was also a BBOXX customer). That presence could have also biased responses of some customers who might have wanted to take an opportunity to express their concerns or get answers to their own questions related to their systems. All efforts were made to avoid such misunderstandings, also through familiarising every participant with the study description and informed consent.
- Recall bias: some participants had been already using their systems for a relatively long period of time at the time of data collection and recalling what their lives were like before they adopted a SSHS might have been difficult and not always fully accurate. Therefore, there is a risk that some answers were subject to a recall bias.
- The sample of participants of PPWs was relatively small (20 HHs). However, from inception it was not aimed to be statistically significant but rather offer

in-depth insights into the realities of SSHSs use in HHs across Rwanda, which complemented the results of surveys and FGs. However, it remains a small sample and the results are not representative of the entire population.

- The selection of 'normal' status customers only from the pool of all customers who were in BBOXX's database at the time of sample selection. 'Normal' status customers were selected in order to be able to examine the lived experience of using a SHS in the household where the system was definitely being used. The other statuses of customers would prohibit such an investigation as 'delayed', 'defaulted' and 'repossessed' status customers were either not using their systems at the time ('delayed' and 'defaulted' would mean systems off) or no longer had them ('repossessed'). It has to be acknowledged that it excluded households where SHSs had been adopted but the experience was different yet represented a reality of the same validity as in the case of 'normal' status customers. The limited scope of this study meant that it was impossible to consider and examine those alternative realities of energy use but it is recommended that research into the adoption of SHSs and subsequent loss of the energy services provided by such technologies and providers like BBOXX or similar is conducted. It could improve the understanding of what factors cause defaults and repossessions, and how those impact on the households and their access to and use of energy. It could greatly benefit the off-grid solar sector and assist in the efforts to provide energy access to all households in need in the most suitable manner, minimising the risk of them losing access to energy services.
- Researcher's bias might have occurred as a result of close work with the BBOXX team and the likelihood of being impacted by the provider's work which might have obscured full objectivity, even if all efforts have been made to avoid it and at various stages of the work the researcher has removed herself from the industry partner representatives in order to minimise the risk of bias. As this study was a collaborative study between BBOXX and UCL, consultations on the scope of the research were frequently conducted with the representatives from BBOXX, however, the researcher was the one ultimately making the decisions about the study and its scope, research questions and study design. The most considerable influence on those were from the UCL

supervisory team rather than the industry partner's supervisor, who was consulted and informed but otherwise not actively involved in the study.

- Women's participation in the study: sampling was purposive and that in itself has limitations as it does not follow the random sampling path which is considered to be the most representative one. However, while it might have been a limitation, it also allowed for gaining insights from those who are less represented and heard by the nature of SHSs ownership which tends to lie with the men.
- The researcher's lack of knowledge of the local language (Kinyarwanda) and the need for relying on translations and write ups of RAs: some insights and sentiments, attitudes and 'objective truths' might have been lost in translation and in the process of managing the data for the purposes of being analysed by the researcher, who also has her own point of view and level of subjectivity. This study does not, however, claim to present the only truth about the use of SHSs but rather an interpretation of some of those realities as shared by the users of SSHSs in NW of Rwanda, with insights from other regions being represented in a very limited way.
- It has to be acknowledged that customer experience of accessing energy via SSHSs and the experience of services which are provided might be different now that the business model of the company has changed, and the services offered have been changed on several occasions since the commencement of this study. Additionally, the way end-users communicate with BBOXX might vary from what it used to be at the time data was collected for this research.
- Lack of inclusion of *Mutuelle* (health insurance) in the priority expenditures: given the wide coverage and the fact that a considerable proportion of the rural population regularly pay for health insurance, it should have been included in the list of priority expenditures. However, it was missed as it did not get mentioned in FGs which guided the design of the survey.
- And finally, it needs to be acknowledged that this is not a comprehensive study of how rural HHs access different services but only one way of accessing energy which is also limited in a way that it does not currently support a critical energy need which is cooking. Other missing services, such as access to water (whether for household use or potable water), which means that HH members,

often women, still spend time on fetching water a few times a week and it can be very costly (not only in terms of time but also money), and access to improved sanitation, have been identified in this study but have not received much attention due to time and scope limitations. However, it is highly important that rural development is approached in a comprehensive manner and includes access to all basic needs and services as access to energy alone is not a panacea to the challenges faced by rural HHs.

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Appendix 1: BBOXX SMART Solar Home System - Examples

Solar Panel & Control Unit (with a lead acid battery)

Appliances (light bulb, TV, radio, phone charging port, tube/portable light)

The same system as shown in the infographics above shown here on a shelf of one of the provider's shops. Photo Credit: BBOXX.

Appendix 2: Multi-tier matrix for access to household electricity supply

TABLE ES.1

Multi-tier Matrix for Access to Household Electricity Supply

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
1. Capacity	Power[1]		Very Low Power Min 3 W	Low Power Min 50 W	Medium Power Min 200 W	High Power Min 800 W	Very High Power Min 2 kW
	AND Daily Capacity		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
	OR Services		Lighting of 1,000 lmhrs per day and phone charging	Electrical lighting, air circulation, television, and phone charging are possible			
2. Duration	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 1 hrs	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
3. Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration < 2 hours
4. Quality						Voltage problems do not affect the use of desired appliances	
5. Affordability					Cost of a standard consumption package of 365 kWh per annum is less than 5% of household income		
6. Legality						Bill is paid to the utility, prepaid card seller, or authorized representative	
7. Health and Safety						Absence of past accidents and perception of high risk in the future	

[1]The minimum power capacity ratings in watts are indicative, particularly for Tier 1 and Tier 2, as the efficiency of end-user appliances is critical to determining the real level of capacity, and thus the type of electricity services that can be performed.

TABLE ES.2

Multi-tier Matrix for Access to Household Electricity Services

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Tier criteria	Not applicable	Task lighting Phone charging	General lighting Television Fan (if needed)	Tier 2 AND Any medium-power appliances	Tier 3 AND Any high-power appliances	Tier 4 AND Any very high-power appliances

TABLE ES.3

Multi-tier Matrix for Electricity Consumption

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Annual consumption levels, in kilowatt-hours (kWh)	<4.5	≥4.5	≥73	≥365	≥1,250	≥3,000
Daily consumption levels, in watt-hours (Wh)	<12	≥12	≥200	≥1,000	≥3,425	≥8,219

Source: World Bank (2015a). Beyond Connections. Energy Access Redefined. Online at http://www.worldbank.org/content/dam/Worldbank/Topics/Energy%20and%20Extract/Beyond_Connections_Energy_Access_Redefined_Exec_ESMAP_2015.pdf.

Appendix 3: Categorisation of off-grid solar products and their sales volumes between 2015 and 2016

Market segment (solar PV capacity)	Service provided	Corresponding Mtf energy access tier	Volume of products sold in sub-Saharan Africa (July 2015–June 2016)
0–1.5 Wp	Single light only	**Tier 0**	2,178,836 (53%)
1.5–3 Wp	Single light + phone charging	**Tier 1**—Task lighting AND Phone charging	1,161,280 (28%)
3–10 Wp	Multiple lights + phone charging		513,435 (12%)
11–20 Wp	Entry level standalone solar system (3–4 lights, phone charging and low power appliances (e.g., radio, fan))		100,463 (2%)
21–49 Wp	Basic capacity standalone solar system (above plus power for TV & extended capacity)	**Tier 2**—General lighting AND Phone Charging AND Television AND Fan (if needed)	64,296 (2%)
50–100 Wp	Medium capacity standalone solar system (above but with extended capacity)		64,328 (2%)
100 Wp+	Higher capacity standalone solar system (above but with extended capacity)	**Tier 2** (Large systems could qualify for Tier 3)	44,163 (1%)

Source: Muchunku et al., 2018. Diffusion of solar PV in East Africa: What can be learned from private sector delivery models? *WIRES Energy and Environment*, (May 2017), p.4.

Appendix 4: Focus Group 1 questions and themes

Theme/questions
1. General
a) Age
b) Profession (male & female):
c) Distance from the grid (are you aware of it? Can you approximate it?)
d) Are you likely to be connected to the grid in the next 6 months to 1 year?
e) What other energy sources, other than the SHS, do you currently use?
f) How much do you spend on energy? (per month, approximately)
2. Story of solar and SSHS in the HH:
a) Could you tell us why you purchased a BBOXX?
b) What motivated you? What factors did you consider before purchasing a BBOXX?
c) What do you think about the pricing of it?
d) What do you think about its technical specifications?
e) What do you think about its design and how it integrates in your HH?
3. In-HH use of energy:
a) Who uses the appliances the most? Which member of the HH? Why?
b) What's the most useful appliance that you own? Why?
c) Who is responsible for the system? (taking care of it, maintaining it, making sure it's used correctly)
d) Who makes the payments for the system?
e) How is energy used in the HH? What is it mostly used for? (it includes other sources other than SHS)
f) What energy source did you use to rely on most before getting the system? How did energy sources use to be used before getting the SHS?
g) What are the key observed/noticed differences in using energy sources before and now with the SHS in the house?
4. In-HH changes due to SHS/in-HH use of SHS:
a) Lifestyle changes
b) New practices and habits: any important changes in how one goes about their daily routine? If so- how? In what way has it been shaped by the use of SHS?
c) Light switching: are the lights used only when in the house? Why?
d) For what purposes are they mostly needed?

e) What are the devices connected to the USB ports
f) Are phones from friends/family charged through the system?
g) What are the dynamics of the system use in the HH? Who takes priority in using it? For what purposes?
h) What are the most important uses of the system in your family?
i) How do you prioritise the expenses in the household? Where does your system/having a system in your priorities?
j) What are the top three priorities in terms of services you want secure for the household? Have they changed since having the system?
k) How often do you watch TV? Does the whole family watch TV? When do you usually watch TV?
5. Needs and aspirations:
a) What are your biggest needs when it comes to energy use?
b) Do you feel the system meets all your needs? If so- why? If not- why?
c) Would you like to eventually get connected to the grid? If so- why? If not- why?
d) How/what do you imagine your energy source (whether a SHS or any other source of energy) to be in 5-10 years? Why?
e) What are the most important needs in your family that you would like to have satisfied that are not satisfied at the moment? Do you think this system can meet them? If not- what do you think is needed to meet them?
f) What would be the next appliance that you would like to have in your HH? Why? What impact do you think it would make on the HH/why would it be important for the household?
g) Has your system ever stopped working (for whatever reason)?
h) What impact did it have on the HH when appliances stopped working?
i) What was the cost and time implication of getting disconnected from the system (whether because e of not paying or because of the system breaking down)?
6. Using the system for productive uses/business
a) Are any appliances used for productive uses? For income generation? If so- which ones and how? And how much income is brought to the HH from these activities?
b) If you do not use the system for productive activities- would you like to in the future? Why? Why not?
c) What other appliances would you like that could make income generation possible? Why?
7. Energy source: solar
a) How much do you know about solar energy?
b) Do you see it as a reliable source of energy?
c) Do you feel it can provide you with enough energy? Why? Why not?

d) Do you often run out of energy from your system?
e) If so, when does it usually happen?
f) Do you think you use the system correctly?
g) Does everyone in the HH know how to use the system correctly?
h) Would you like to receive more training on how to use the system, if it was made available to you?
i) Do you see your system as a permanent or temporary solution for having electricity in your house?
j) Do you think a grid connection will arrive eventually and if so- when do you think it will be?
k) How does the village community perceive solar systems? What do they think of them?
l) How important is it/ was it for you to learn about how reliable the system is from someone before purchasing it?
8. Services:
a) How have you been using BBOXX's services?
b) Have you found them useful/Have they met your needs? Why? Why not?
c) Do you feel BBOXX deliver good service? Why or why not?
EXERCISE (mostly impossible, participants unable to draw and visualise energy use over time):
9. Could you draw us a brief diagram demonstrating how you use the energy from the system throughout the day (x-axis: time of the day; y-axis: amount of energy used kWh)
Additional questions (discussion permitting):
Would you use a solar-powered cook stove if it was available?
How do you choose what you use for cooking?
How much time does the woman in the HH save as a result of having the system (on average)?
How much more time do the kids spend at home, on average, thanks to the system?
How much more time, on average, do the kids study for thanks to the system?
Do women in the HH get training on how to use the system?
Do the kids in the HH get training/demonstration on how to use the system?
Is there a water connection in the HH?
If you use any system appliances for income generation, how much, on average, do you make off it per week?
Have you noticed any changes in the community since the solar systems first appeared here?
If you're a farmer, what is your key crop?

Appendix 5: Focus Group 2 (follow up) questions and themes

Theme/questions

ENERGY IMIHIGO
1) How long have in-HH imihigo been around?
2) How do HHs decide on their imihigo?
3) Whom are they accountable to?
4) How common are energy imihigo? How are they decided? What do they mean at a village level?
5) How do HHs decide on what energy source to adopt? Are these decisions influenced by the village-level imihigo? (both in terms of energy and other imihigo)
SAFETY (98% said they felt safer now that they have the system, the key question is- why?)
1) What is the perceived threat?
2) What is the safety impact on the woman & the girl in the family vs the man and the boy in terms of safety/security?
3) Why do you feel safer? Who benefits most and in what way from improved safety?
SAVINGS
1) Do you feel you save now that you have the SHS?
2) Do you actively calculate the savings/how much you spend on energy now vs before? How much savings have you been able to generate- can you tell?
3) Did you consider the savings aspect before purchasing the system?
4) Do you feel the system is affordable? If so- what does affordability mean to you in this regard? And what does affordability mean to you more generally (not just in terms of the BBOXX system)?
5) How important are SACCOs for you? Do you rely on them for key purchases in the HH? Did you use them when you decided to buy the system?
SERVICE
1) Do you feel you have established a relationship with BBOXX? If so- how? What makes it for you/what does it mean to you? Is it just because you have their product or is it all the interactions to build it?
SYSTEM USE
1) Is the system easy to use?
2) Are you confident about all aspects of the system use? If not- which aspects are you not confident about?

3) Do you feel you know enough about how it works to use it properly? Is it straightforward? Or do you feel you don't need to know much/is it enough to just make sure it is working properly?
Follow up questions according to discussion!

Appendix 6: Survey questionnaire (including PPI questions): English and Kinyarwanda

label::English	label::Kinyarwanda
A. General	A. Rusange
Customer ID	Nimero y'umukiriya
1. Gender	1. Igitsina
2. How old are you?	2. Imyaka
3a. Education (Male)	3a. Amashuli y'umugabo
Specify other:	Sobanura
3b. Education (Female)	3b. Amashuli y'umugore
Specify other:	Sobanura:
4a. Profession (Male):	4a. Umwuga w'umugabo
Specify other:	Sobanura:
4b. Profession (Female):	4.b Umwuga w'umugore
Specify other:	Sobanura:
5. Number of HH members (total):	5. Umubare w'ababa mu rugo (bose):
6. How long does it take you to walk to the nearest grid?	6. Bigutwara igihe kingana gute kugera k'umuriro w'amashanyarazi ukwegereye?
7. Are you likely to be connected to the grid in the next 6 months to 1 year?	7. Ese mu mezi atandatu kugera ku mwaka biri imbere mwaba muteganya kuzazana mashanyarazi
Specify other:	Sobanura:
8. When did you join BBOXX?	8. Ni ryari Waguze Umurasire wa BBOXX?
9. Which BBOXX system do you have?	9. Ni iyihe paki ya BBOXX ukoresha?
10. How much do you spend on SHS per month?	10. Ese mwishyura amafaranga angahe k' umuriro ku kwezi?
11a. What other energy sources, other than the SHS, do you currently use?	11. Ni Ubuhe bundi bwoko bwimbaraga z'umuriro ukoresha?
Specify other:	Sobanura:
11b. How much do you spend on them per month?	11b. Mubutangaho amafaranga angahe?
12. Which statement most accurately describes you:	12.h) Ese muri ibi: bikurikira niki wumva kikuranga
Specify other:	Sobanura:
B. Motivations and Perception of SHS	B. Motivation and perceptiom
1. Why did you purchase a BBOXX system?	1. Watubwira impamvu waguze BBOXX? N'ibihe wagendeheyo mbere yo kugura BBOXX?
Specify other:	Sobanura:
2. What motivated you? What factors did you consider before purchasing a BBOXX?	2. N'ibihe wagendeheyo mbere yo kugura BBOXX?
Specify other:	Sobanura:
2a. At the household level, was getting electricity one of the targets among your imihigos at the time you purchased the system?	2a. Kugira umuriro mu rugo rwanyu byaba byarigeze kuba umwe mu mihigo mwari mufite igihe mwaguraga umurasire?
2b. Are you aware if at the umudugudu level getting electricity was among the imihigo targets at the time you purchased the system?	2b. Ese waba uzi niba igihe mwaguraga umurasire byari mu mihigo y'umudugudu?
2c. Are you aware if at the umudugudu level getting electricity is among the imihigo targets now?	2c. Ese waba uzi niba kuzana umuriro muri aka gace ari umwe mu mihigo y'umudugudu wanyu muri iki gihe?
3. What do you think about the price of the system?	3. Ubona gute ibiciro byayo?
4a. What do you think about its quality?	4a. What do you think about its quality?
Specify other:	Sobanura:
4b. Why?	4b. Kubera iki?
5a. What do you think about its design and how it integrates in your HH?	5a. N'iki utekereza ku miterere yabyo nuko bibafasha mu rugo rwanyu?"
Specify other:	Sobanura:
5b. Why?	5b. Kubera iki?
6. How do the community members perceive solar systems?	6. Abaturage bo muri aka gace bumva gute umuriro w'imirasire y'izuba?
C. In-HH Use of Energy	C. In-HH Use of Energy
1a. Who uses the appliances the most? Which member of the HH?	1a. Ninde muntu ukoresha ibikoresho bya BBOXX cyane? Ni kuzihe mpamvu?
Specify other:	Subanura

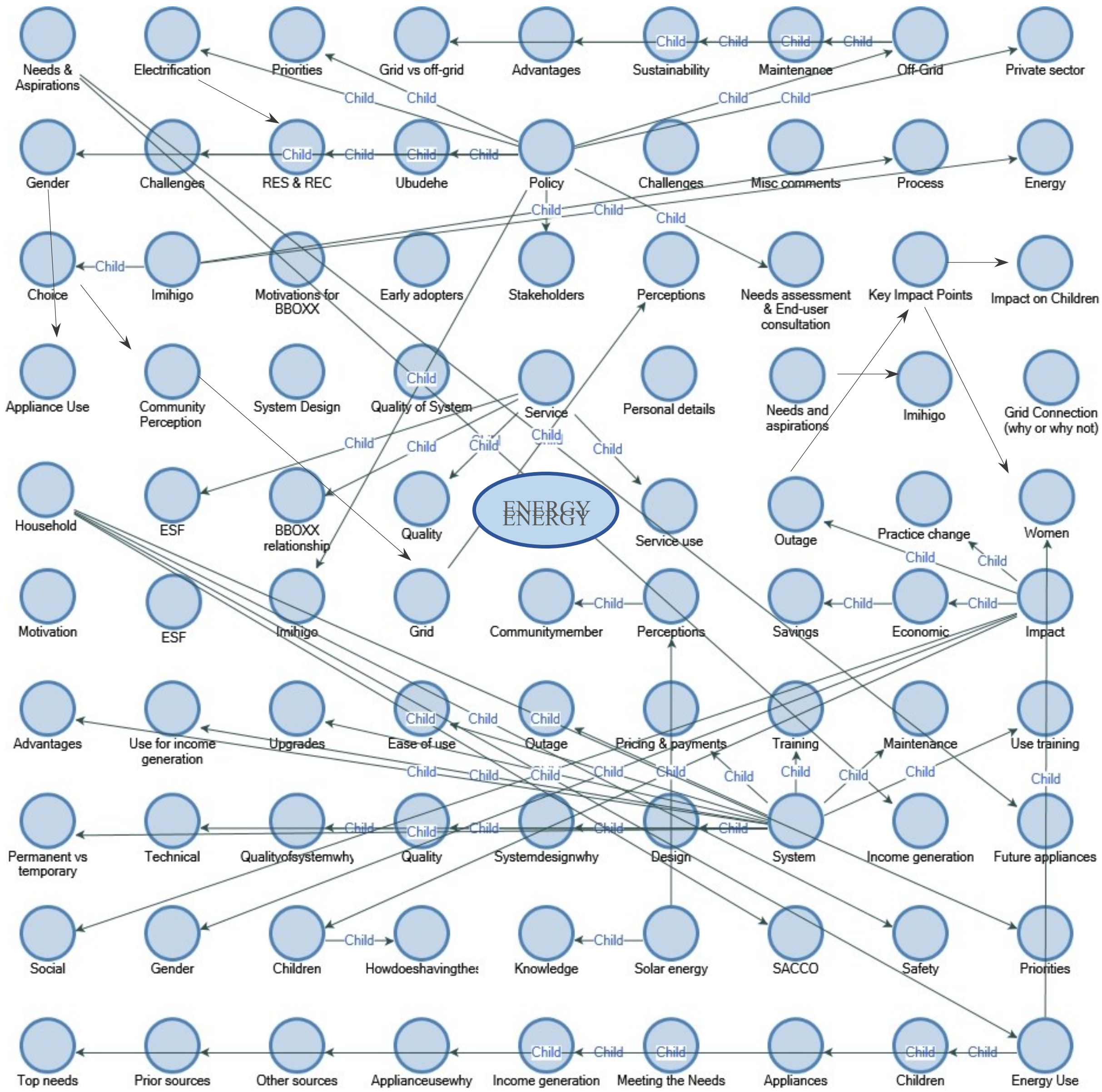
1b. Why?	1b. Kubera iki?
2. What's the most useful appliance that you own?	2. Nikihe gikoresho k'ingirakamaro utunze? Kubera iki?
Specify other:	Sobanura:
3. Who is responsible for the system? (taking care of it, maintaining it)	3. Ninde ushinzwe sisitemu? (mu kuyitaho, kuyikoresha yagize ikibazo, kumenya ko yakoreshejwe neza)
Specify other:	Sobanura:
4. Who makes the payments for the system?	4. Ninde wishyura system
Specify other:	Sobanura:
5. How is energy used in the HH? What is it mostly used for? (it includes other sources other than SHS)	5. Ni gute mukoresha umuriro hano murugo? Ni mu biki muwukoreshamo cyane?
Specify other:	Sobanura:
6. What energy source did you use to rely on most before getting the system?	6. Ni ubuhe bwoko bw'umuriro mwakoreshaga cyane mbere yuko mugura umuriro w'imirasire y'izuba?
Specify other:	Sobanura
7. How did energy sources use to be used before getting the SHS?	7. Ni gute mwabukoreshaga?
Specify other:	Sobanura:
8. What do you primarily use for cooking?	8. Ni ibiki by'ibanze mukoresha mu guteka?
Specify other:	Sobanura:
9. Why?	9. Kubera iki?
D. In-HH Changes Due to SHS	D. In-HH Changes Due to SHS
1. How does having the solar system affects your life?	1. Ni iki kugira umurasire byahinduye mu buzima bwawe?
Specify other:	Sobanura:
2a. How much time in hours per day do you save by having the system?	2a. Ni amasaha angahe mwungutse kubera kugira umuriro mu rugo?
2b. How much time in hours per day does the female in the HH save by having the system?	2b. Ni amasaha angahe y'inyongera umugore wawe yaba yarungutse?
3. When do you switch on the lights?	3. Ni ryari mucana amatara?
specify other:	Sobanura
4. For what purposes are they mostly needed?	4. Ni kuzihe mpamvu mukunda gucana amatara?
Specify other:	Sobanura:
5. Do you feel safer because of having the lights?	5. Wumva utekanye kuba ufite amatara?
6a. Where in your house is the system?	6a. Ni ahagana he munzu yawe system ibitse?
Specify other:	Sobanura:
6b. Why?	6b. Kubera iki?
7. What devices do you connect to your system?	7. Ni ibihe bikoresho mucomeka kuri sisitemu yawe?
Specify other:	Sobanura:
8. Are phones from friends/family charged through the system?	8. Ese mwaba musharijira telefoni incuti cyangwa abaturanyi kuri iyi sisitemu?
9. Do you charge them for charging their phones?	9. Ese mwaba mubishyuza?
Specify other:	sobanura
10. How much do you make per week by charging them?	10. Ubona amafaranga angahe mu gusharisha mu cyumweru?
11. How does having the solar system affect the life of your children?	11. Hari ikintu kugira sisitemu y'imirasire byaba byarahinduye mu buzima bwabana bawe?
12. Do children study more/longer as a result of having the system?	12. Abana baba biga amasaha yiyongereyeho ugereranije na mbere?
13. How much longer per day?	13. Yaba ari amasaha angahe yiyongereyeho?
Expenses in the HH	Ibitwara amafaranga mu rugo
14. How do you prioritise the expenses in the household?	14. N'ibiki wishyura mbere y'ibindi mu rugo?
1st choice	Hitamo 1
2nd choice	Hitamo 2
3rd choice	Hitamo 3
Specify other:	Sobanura:

Expenses in the HH before buying the HH	Ibitwara amafaranga mu rugo nyuma yo kugura BBOXX
15. How did you prioritise the expenses in the household before having BBOXX?	15. Ni ibiki wishyuraga mbere yibindi mbere yo kugura BBOXX
1st choice	Hitamo 1
2nd choice	Hitamo 2
3rd choice	Hitamo 3
Specify other:	Sobanura:
16. Do you have TV signal coverage in your house?	16. Hano mujya mureba TV? Mubona signal?
16a. Do you watch other content on TV? (movies etc.)	16a. Mujya mureba nkindirimbo zo kuri flash se cg filimi?
17. How often do you watch TV?	17. Ese ni kangahe ureba televiziyo?
Specify other:	Sobanura
17a. How often do you watch other content on TV?	17a. Ni kangahe mureba ibindi nkindirimbo cg filimi zo kuri flash?
Specify other:	Sobanura:
18. Does the whole family watch TV together?	18. Ese umuryango wawe wose waba ureba televiziyo?
Specify other:	Sobanura:
18a. Does the whole family watch other content on TV together?	18a. ese umuryango wawe wose waba ureba amafilimi n'indirimbo zo kuri flash?
Specify other:	Sobanura?
19. When do you usually watch TV?	19. Ese ni ryari ukunda kuyireba?
Specify other:	Sobanura?
19a. When do you usually watch other content on TV?	19a. Ese ni ryari ukunda kureba izo filimi n'indirimbo zo kuri flash?
Specify other:	Sobanura:
E. Needs and Aspirations	E. Needs and Aspirations
1. How satisfied are you with the amount of energy provided by the system?	2. Ese waba unyuzwe n'umuriro ubona?
2a. Do you feel the system meets all your needs?	2a. Use ubona sisitemu ihaza ibyo ukenera (needs)?
specify other:	sobanura:
2b. Why?	2b. Kubera iki?
3a. What would be the next appliance that you would like to have in your HH?	3a. Ni ikihe gikoresho wifuza gutunga munzu yawe?
Specify other:	Sobanura:
3b. Why?	3b. Kubera iki?
4. Has your system ever stopped working for longer than a day/been switched off for longer than a day?	4. Ese sisitemu yawe yaba yarigeze guhagarara birenze umunsi wose?
5. How did it affect you?	5. Ese ni ibiki byaba byaraguhangabanije ho?
6a. What was the cost implication of having the system not working/switched off?	6a. Ese byabatwaye amafaranga angahe mu gihe mutari sisitemu yari yapfuye? (Yaba mu gihe mutabashije kwishyura cyangwa se mu gihe sisitemu yari yapfuye)
6b. What was the time implication of having the system not working/switched off?	6a. Ese byabatwaye umwanya ungana gute mu gihe mutari sisitemu yari yapfuye? (Yaba mu gihe mutabashije kwishyura cyangwa se mu gihe sisitemu yari yapfuye)
7a. Would you like to eventually get connected to the grid?	7a. Ese wumva waba umufatabuguzi ku murongo w'amashanyarazi? "
7b. Why?	7b. Kubera iki?
F. Productive Uses of SHS	F. Productive Uses of SHS
1. Are any appliances used for productive uses/income generation?	1. Ese hari ibikoresho mukoresha mu bikorwa bibyara inyungu? Byaba byinjiza amafaranga? "
2. Which ones?	2. Byaba ari ibihe?

3. How much per week do you make from using them?	3. Mu cyumweru mubona angahe avuye mu kubikoresha?
4. Would you like to use system appliances for productive uses/income generation in the future?	4. Wumva ushaka kuba wazakoresha sisitemu mu bikorwa bibyara inyungu mu gihe kizaza?
5. What other appliances do you think would make income generation possible?	5. Ni ibihe bikoresho wumva wakoresha bya kubyarira inyungu?
G. Energy Source: Solar	G. Energy Source: Solar
1. How much do you know about solar energy?	1. Uzi ibingana iki ku mirasire y'izuba?
Specify other: 2. Do you see it (solar) as a reliable source of energy?	Sobanura: 2. Uyabona nkisoko irambye y'umuriro?
Specify other: 3. Do you feel it can provide you with enough energy now and in the future?	sobanura: 3. Wumva ashobora kuguha umuriro uhagije muri iki gihe ndetse n'ikiri imbere?
4. Do you run out of energy from your system?	4. Umuriro ujya ushira kuri iyi sisitemu yawe?
5. When does it usually happen?	5. Bikunda kuba ryari?
Specify other: 6. Do you think you use the system correctly?	Sobanura: 6. Wumva ukoresha sisitemu neza?
7. Who in the HH has been provided with training on how to use the system?	7. Ninde wakiriye amahugurwa yo gukoresha iyi sisitemu
Specify other: 8. During training, were you told what the maximum time you can use the system appliances for is (per day)?	Sobanura: 8. Mu mahugurwa mwahawe, baba barababwiye amasaha ntarengwa yogukoresha sisitemu (Ku munsi)?
8a. What was it?	8a. Bababwiye ko ari igihe kingana gute?
8b. Do you obey this recommendation?	8b. Ese mwaba mukurikiza icyo gihe bababwiye?
9. Would you like to receive more training on how to use the system, if it was made available to you?	9. Wumva ukeneye andi mahugurwa yo gukoresha sisitemu mu gihe yaba aboneka?
10. Do you see your system as a permanent or temporary solution for having electricity in your house?	10. Ubona iyi sisitemu ari igisubizo kirambye cy'umuriro mu nzu yawe?
H. Services 1. How have you been interacting with BBOXX?	H. Services 1. Kuva mwagura BBOXX mujya mubasha kuba mwavugana na BBOXX?
Specify other: 2. Have you found them helpful?	Sobanura: 2. Ese ubona bagufasha?
3. Do you feel you have established a relationship with BBOXX?	3. Ese wumva hari umubano ufitanye na BBOXX?
4a. Do you feel BBOXX deliver good services?	4a. Ese wumva BBOXX itanga serivisi nziza
4b. Why? 5. Do you have any other comments about BBOXX's services you would like to share?	4b. Kubera iki? 5. Wumva hari ikindi ushaka kkuba watubwira tutavuze haruguru?
6. Which solar energy service providers/companies do you know?	6. Ni abahe bantu batanga imirasire uzi?
Specify other:	Sobanura
matrix_exercise Matrix Exercise Lights Tube light Phone charging	matrix_exercise Umwitozo wa matirisi Amatara Itara rirerire Gusharija telefone

Radio TV Other	Radiyo Televiziyo Ikindi
I. PPI	I. PPI
1. How many households members are 18 years-old or less	1. Ni abanyamuryango bangahe bafite imyaka 18 kumanura?
2. In the last 12 months, how many household members carried out any agricultural activity (whether farming, livestock, fishing, or forestry) for salary, wages, or in-kind compensation?	2. Mu mezi 12 ashize haba hari abantu hano mu rugo bakoze imirimo y'ubuhinzi-bworozi bakorera amafaranga cyangwa ikindi gihembo?
3. In the last 12 months, how many household members ran or operated a non-farm business for cash or profit for themselves, like a small shop or other income-generating activity?	3. Mu mezi 12ashize, haba hari abantu muri uru rugo bakoze ibikorwa by'ubucuruzi b itari iby'ubuhinzi bahembwa cyangwa bikorera ku giti cyabo waba warakoze uhembwa cyangwa wikorera ku giti cyawe, nk'iduka rito cyangwa ikindi cyose cyakuzanira amafaranga?
4. Can the (oldest) female head/spouse read a letter or a simple note (regardless of language), or has she completed at least Primary 1?	4. Umuntu mukuru (mu myaka) uyobora urugo / umufasha w'igitsina gore ashobora ibarwa cyangwa akandiko gato (birebana n'ururimi) cyangwa yarangije nibura umwaka wa mbere w'amashuri abanza
5. What is the main construction material of the exterior walls?	5. Ni ibihe bikoresho by'ingenzi byubatse inkuta
6. What is the main material used for roofing the main dwelling?	6. Ni ibihe bikoresho by'ingenzi bisakaye inzu yanyu?
7. What is the main source of lighting in the residence of the household?	7. Iyo bwije mucana iki cy'ingenzi kugira ngo munzu yanyu habone?
8. How many beds does the household own?	8. Urugo rwanyu rufite ibitanda bingahe?
9. How many mobile telephones does the household own?	9. Urugo rwanyu rufite telefoni igendanwa zingahe?
10. In the past 12 months, has any household member grown food or other agricultural produce to eat or sell or raised cattle or poultry? If so, then how many head of cattle does the household currently own?	10. Mu mezi 12 ashize hari umuntu wo muri uru rugo wahinze imyaka cyangwa ibindi bihingwa bigenewe kuribwa cyangwa gucuruzwa, woroye amatungo cyangwa ibinyamababa? Niba ari yego bafite amatungo angahe?
11. How many households members were present at least 6 of the last 12 months?	11. Ni abanyamuryango bangahe bari bahari amezi 6 mu mezi 12 ashize?
12. How many households members have 18-years old or younger?	12. Ni abanyamuryango bangahe baba mu rugo bafite imyaka 17 cyangwa kumanura?
13. how many household member, 6 years or older who have practiced any agricultural activity (farming, livestock, fishery or forestry) for pay?	13. Ni abanyamuryango bangahe (bafite imyaka 6 kuzamura) bakoze igikorwa cy'ubuhinzi (ubuhinzi, ubworozi, uburobyi cyangwa se ibyamashyamba) yaba yarakoze yishyurwa?
14. how many household member, 6 years or older who runs or operates non-farm business for cash or profit for themselves?	14. Ni abanyamuryango bangahe (bafite imyaka 6 kuzamura) baba barakoze igikorwa cy'ubucuruzi kitari icy'ubuhinzi yaba yarigeze akora ahembwa cyangwa yikorera?

Appendix 7: Qualitative analysis (NVivo) - project map and relationships (nodes)



Appendix 8: Qualitative analysis (NVivo): Codebook

Nodes: FG1(1-5), FG2(6-10), PPWs, S2+S3 (Survey) (Qualitative)

Name	Description
Challenges	Challenges associated with owning the system/using the system or services
Early adopters	Questions related to testing whether study users were early adopters or not (not elaborated on/not included in the study)
Grid	Questions related to grid connections
Perceptions	Perceptions of connecting to the grid network or using the grid
Household	
Energy Use	Questions around: How is energy used in the HH?
Appliances	What appliances are used and how
Appliance use: why?	Why are they used a certain way and who uses them the most?
Income generation	Questions around income generation with the use of system appliances
Children	Questions around how children use energy
Other sources	Other sources used in the household
Prior sources	Sources which used to be used before adopting a SHS
Top needs	Key needs of the household
Women	Key needs of women
Priorities	Priority expenses in the household
SACCO	Participation in SACCOs and their role in purchasing a SHS
Safety	Questions around safety and whether and how it changes after installing a SHS

Name	Description
Imihigo	Exploration of the imihigo framework and its functioning
Choice	Choices made by household as part of their imihigo (how they prioritise what to focus on etc.)
Energy	Place of energy access in the imhigo framework
Process	Process of imhigo: how, when, why, who etc.
Impact	Impact of energy access
Children	Impact on children
How does having the system affect the life of your children?	Elaboration on the above
Economic	Economic impact of gaining access to energy on the household
Savings	Exploration of whether and how much saving there is post system adoption
Gender	Gender impact
Outage	Impact of outages on the households and their members (e.g. when SHS goes off due to late payment)
Practice change	Practices and how they change post system adoption
Social	Social aspects of energy access
Miscellaneous comments	Various comments shared by study participants
Motivations for BBOXX	Motivations for purchasing a SHS
Needs & Aspirations	Key needs and aspirations of study participants
Future appliances	Aspirations for future appliances and what they are
Income generation	Aspirations for income generation and how prevalent it is
Service	Use of provider’s services
BBOXX relationship	Relationship established with the provider

Name	Description
Quality	Perceived quality of the service
Service use	How the service is used by the adopters
Solar energy	Questions around solar energy and how much is known about it
Knowledge	Knowledge of solar energy and how a SHS works
Perceptions	Perceptions of solar energy and its efficiency/sufficiency
Community members	How community members perceive solar energy and SHSs
System	The physical system: questions on design, HH integration, ease of use, maintenance
Design	Opinions on the system design
System design	
Ease of use	How easy is it to use the system for different HH
Maintenance	Who is in charge of maintenance
Outage	How often HH run out energy/experience outages
Permanent vs temporary	Perceptions of SHSs and whether they are a permanent or temporary solution
Pricing & payments	Issues around pricing and modes of payment
Quality	Perceptions of system quality
Quality of system	What users think of the quality of the system
Technical	Technical challenges with the system
Training	Training on the use of the system and whether it was sufficient
Upgrades	Perceptions and aspirations for upgrading the system
Use training	Potential need for additional training on how to use the system correctly

Nodes\\HH Survey (S2+S3) Qualitative

Name	**Description**
ESF	Energy Service Fee - related questions
Imihigo	Exploration of the theme of imihigo (the working of it, place of energy, meaning etc.)
Key Impact Points	Key impacts associated with gaining access to energy through SHS
Motivation	Reasons and motivations for purchasing a SHS, incl. specifically a BBOXX SSHS
Needs and aspirations	Key needs and aspirations (post-adoption)

Appendix 9: Qualitative analysis (NVivo): node structure

Hierarchical Name

Node

Nodes (All)

Nodes\\Challenges

Nodes\\Early adopters

Nodes\\Grid

Nodes\\Grid\Perceptions

Nodes\\Household

Nodes\\Household\Energy Use

Nodes\\Household\Energy Use\Appliances

Nodes\\Household\Energy Use\Appliances\Applianceusewhy

Nodes\\Household\Energy Use\Appliances\Income generation

Nodes\\Household\Energy Use\Children

Nodes\\Household\Energy Use\Other sources

Nodes\\Household\Energy Use\Prior sources

Nodes\\Household\Energy Use\Top needs

Nodes\\Household\Energy Use\Women

Nodes\\Household\Priorities

Nodes\\Household\SACCO

Nodes\\Household\Safety

Nodes\\Imihigo

Nodes\\Imihigo\Choice

Nodes\\Imihigo\Energy

Nodes\\Imihigo\Process

Nodes\\Impact

Nodes\\Impact\Children

Nodes\\Impact\Children\System affecting children's life

Nodes\\Impact\Economic

Nodes\\Impact\Economic\Savings

Nodes\\Impact\Gender

Nodes\\Impact\Outage

Nodes\\Impact\Practice change

Nodes\\Impact\Social

Nodes\\Misc comments

Nodes\\Motivations for BBOXX

Hierarchical Name

Nodes\\Needs & Aspirations

Nodes\\Needs & Aspirations\Future appliances

Nodes\\Needs & Aspirations\Income generation

Nodes\\Policy

Nodes\\Policy\Challenges

Nodes\\Policy\Electrification

Nodes\\Policy\Gender

Nodes\\Policy\Imihigo

Nodes\\Policy\Needs assessment & End-user consultation

Nodes\\Policy\Off-Grid

Nodes\\Policy\Off-Grid\Advantages

Nodes\\Policy\Off-Grid\Grid vs off-grid

Nodes\\Policy\Off-Grid\Maintenance

Nodes\\Policy\Off-Grid\Sustainability

Nodes\\Policy\Priorities

Nodes\\Policy\Private sector

Nodes\\Policy\RES & REC

Nodes\\Policy\Stakeholders

Nodes\\Policy\Ubudehe

Nodes\\Service

Nodes\\Service\BBOXX relationship

Nodes\\Service\ESF

Nodes\\Service\Quality

Nodes\\Service\Service use

Nodes\\Solar energy

Nodes\\Solar energy\Knowledge

Nodes\\Solar energy\Perceptions

Nodes\\Solar energy\Perceptions\Community members perception of SHS

Nodes\\System

Nodes\\System \Advantages

Nodes\\System \Design

Nodes\\System \Design\Systemdesignwhy

Nodes\\System \Ease of use

Nodes\\System \Maintenance

Nodes\\System \Outage

Nodes\\System \Permanent vs temporary

Nodes\\System \Pricing & payments

Nodes\\System \Quality

Nodes\\System \Quality\Quality of system: why?

Nodes\\System \Technical

Nodes\\System \Training

Reports\\Node Structure Report

Hierarchical Name

Nodes\\System \Upgrades

Nodes\\System \Use for income generation

Nodes\\System \Use training

Nodes\\FG Qs

Nodes\\FG_Qs\\FG1 (Nyarubuye)

Nodes\\FG_Qs\\FG2 (Bigogwe)

Nodes\\FG_Qs\\FG3 (Cyuve)

Nodes\\FG_Qs\\FG4 (Nyagahinga)

Nodes\\FG_Qs\\FG5 (Gakoro)

Nodes\\FG Qs Follow Up

Nodes\\FG_Qs_FollowUp\\FG1 (Raba)

Nodes\\FG_Qs_FollowUp\\FG2 (Gakoro)

Nodes\\FG_Qs_FollowUp\\FG3 (Nyabigoma)

Nodes\\FG_Qs_FollowUp\\FG4 (Karangara)

Nodes\\FG_Qs_FollowUp\\FG5 (TerimbereGashungu)

Nodes\\HH Survey (S2+S3) Qualitative

Nodes\\HH_Interviews_Qualitat\\Appliance Use

Nodes\\HH_Interviews_Qualitat\\Community Perception

Nodes\\HH_Interviews_Qualitat\\Grid Connection (why or why not)

Nodes\\HH_Interviews_Qualitat\\Impact on Children

Nodes\\HH_Interviews_Qualitat\\Meeting the Needs

Nodes\\HH_Interviews_Qualitat\\Quality of System

Nodes\\HH_Interviews_Qualitat\\System Design

Nodes\\Insights PPWs

Nodes\\Insights-field-exhibition\\ESF

Nodes\\Insights-field-exhibition\\Imihigo

Nodes\\Insights-field-exhibition\\Key Impact Points

Nodes\\Insights-field-exhibition\\Motivation

Nodes\\Insights-field-exhibition\\Needs and aspirations

Nodes\\Insights-field-exhibition\\Personal details

Hierarchical Name

Nodes\\Participatory_Photo_Feedback

Nodes\\Participatory_Photo_Feedback\\Photo Workshop Feedback

Appendix 10: Poverty Probability Index (PPI) measurement tool (previously Progress out of Poverty)

PPI® for Rwanda 2010

PROGRESS out of POVERTY®
A Grameen Foundation Initiative

Important: A PPI score must be converted into a poverty likelihood using the PPI Look-up Table.

Indicators	Responses	Score
1. How many household members are 18-years-old or less?	A. Five or more	0
	B. Four	2
	C. Three	6
	D. Two	11
	E. One	20
	F. None	29
2. In the last 12 months, how many household members carried out any agricultural activity (whether farming, livestock, fishing, or forestry) for salary, wages, or in-kind compensation?	A. Two or more	0
	B. One	3
	C. None	6
3. In the last 12 months, how many household members ran or operated a non-farm business for cash or profit for themselves, like a small shop or other income-generating activity?	A. None	0
	B. One	3
	C. Two or more	5
4. Can the (oldest) female head/spouse read a letter or a simple note (regardless of language), or has she completed at least Primary 1?	A. No	0
	B. Yes	2
	C. No female head/spouse	4
5. What is the main construction material of the exterior walls?	A. Mud bricks, logs with mud, plastic sheeting, or other	0
	B. Mud bricks with cement (stucco), oven-fired bricks, logs with mud and cement, stones, cement blocks, or wooden planks	5
6. What is the main material used for roofing the main dwelling?	A. Thatch/leaves/grass, clay tiles, bamboo, plastic/plywood/non-permanent materials, or other	0
	B. Metal sheets/corrugated iron, or concrete	3
7. What is the main source of lighting in the residence of the household?	A. Firewood	0
	B. Batteries and bulb, biogas, or other	5
	C. Lantern (agatadowa)	7
	D. Candle, or oil lamp	9
	E. Electricity (from any source), generator, or solar panel	20
8. How many beds does the household own?	A. None	0
	B. One	3
	C. Two	5
	C. Three or more	9
9. How many mobile telephones does the household own?	A. None	0
	B. One	5
	C. Two or more	12
10. In the past 12 months, has any household member grown food or other agricultural produce to eat or sell or raised cattle or poultry? If so, then how many head of cattle does the household currently own?	A. Did not farm	0
	B. Farmed, but no cattle	1
	C. Farmed, one head	3
	D. Farmed, two or more heads	7
	Total Score:	

This PPI was created in April 2016 using Rwanda's 2010/11 Integrated Household Living Standards Survey by Mark Schreiner of Microfinance Risk Management L.L.C., developer of the PPI. For more information, please visit www.progressoutofpoverty.org.

GF GRAMEEN FOUNDATION

www.grameenfoundation.org | Headquarters: 1101 15th Street NW, 3rd Floor, Washington DC 20005 USA

Source (all images): Poverty Probability Index (PPI), 2018. Rwanda. Online at https://www.povertyindex.org/country/rwanda.

Back-page Roster: Household Membership And Occupation

PROGRESS out of POVERTY®
A Grameen Foundation Initiative

Read to the respondent: *Please tell me the names and ages of all members of your household. A household is a person or group of persons, related or unrelated, who—for at least 6 of the last 12 months—normally live and eat together in the same dwelling unit.* Record names, ages, and presence. List the head of the household first, even if he/she is not the respondent, is not a participant in your organization, or is absent. For your own later use with the fourth scorecard indicator, note the name of the (oldest) female head/spouse (if she exists). Mark whether each person is a household member based on the full set of rules in the "Guidelines to the Interpretation of Indicators". Count the members, and record the total in the scorecard header next to "Number of household members:". Mark each member who is 18-years-old or younger, count them, and circle the response to the first scorecard indicator.

For each household member who is at least 6-years-old, ask: *In the last 12 months, did <name> carry out any agricultural activity (whether farming, livestock, fishing, or forestry) for salary, wages, or in-kind compensation?* Also ask: *In the last 12 months, did <name> run or operate a non-farm business for cash or profit for themselves, like a small shop or other income-generating activity?* Based on the responses, circle responses for the second and third scorecard indicators.

Keep in mind the full rules in the "Guidelines for the Interpretation of Indicators".

First Name	Age	Present at least 6 of the last 12 months?	Is <name> a household member? (apply rules)	Is <name> a member and 18-years-old or younger)?	If <name> is 6-years-old or older, then in the last 12 months, did he/she . . . Do any agricultural activity (whether farming, livestock, fishing, or forestry) for pay?	Run or operate a nonfarm business for cash or profit for themselves?
1.		No Yes	No Yes	Not member >18 < =18	Not member/<6 No Yes	No Yes
2.		No Yes	No Yes	Not member >18 < =18	Not member/<6 No Yes	No Yes
3.		No Yes	No Yes	Not member >18 < =18	Not member/<6 No Yes	No Yes
4.		No Yes	No Yes	Not member >18 < =18	Not member/<6 No Yes	No Yes
5.		No Yes	No Yes	Not member >18 < =18	Not member/<6 No Yes	No Yes
6.		No Yes	No Yes	Not member >18 < =18	Not member/<6 No Yes	No Yes
7.		No Yes	No Yes	Not member >18 < =18	Not member/<6 No Yes	No Yes
8.		No Yes	No Yes	Not member >18 < =18	Not member/<6 No Yes	No Yes
9.		No Yes	No Yes	Not member >18 < =18	Not member/<6 No Yes	No Yes
10.		No Yes	No Yes	Not member >18 < =18	Not member/<6 No Yes	No Yes
Members:			#"Yes"	#<=18	#"Yes"	#"Yes"

This PPI was created in April 2016 using Rwanda's 2010/11 Integrated Household Living Standards Survey by Mark Schreiner of Microfinance Risk Management L.L.C., developer of the PPI. For more information, please visit www.progressoutofpoverty.org.

Look-up Tables

The following look-up tables are used to convert PPI scores to poverty likelihoods: National Poverty Lines.

PPI Score	Food	100% National	150% National	200% National	Poorest half below 100% national
0 – 4	98.3	99.5	100.0	100.0	98.2
5 – 9	77.2	93.4	98.1	99.2	75.6
10 – 14	72.0	90.3	97.7	99.1	69.7
15 – 19	57.3	83.2	95.6	98.3	56.3
20 – 24	38.7	71.2	91.0	96.9	38.6
25 – 29	28.8	63.0	90.6	96.1	28.3
30 – 34	19.3	50.2	83.0	94.4	18.2
35 – 39	14.0	34.7	70.5	87.1	12.6
40 – 44	9.2	27.7	58.4	78.9	6.5
45 – 49	5.0	17.0	45.1	67.8	3.4
50 – 54	2.7	11.0	30.5	56.3	2.0
55 – 59	0.6	6.0	25.4	42.8	0.5
60 – 64	0.4	2.0	14.0	27.8	0.0
65 – 69	0.2	0.9	7.3	18.6	0.0
70 – 74	0.0	0.0	3.6	9.9	0.0
75 – 79	0.0	0.0	1.3	7.2	0.0
80 – 84	0.0	0.0	0.5	4.9	0.0
85 – 89	0.0	0.0	0.4	1.0	0.0
90 – 94	0.0	0.0	0.0	0.0	0.0
95 – 100	0.0	0.0	0.0	0.0	0.0

This PPI was created in April 2016 using Rwanda's 2010/11 Integrated Household Living Standards Survey by Mark Schreiner of Microfinance Risk Management L.L.C., developer of the PPI. For more information, please visit www.progressoutofpoverty.org.

PPI® for Rwanda 2010

Look-up Tables

The following look-up tables are used to convert PPI scores to poverty likelihoods: International 2005 PPP Lines

PPI Score	$1.25/day 2005 PPP	$2.00/day 2005 PPP	$2.50/day 2005 PPP	$5.00/day 2005 PPP	$8.44/day 2005 PPP
0 - 4	100.0	100.0	100.0	100.0	100.0
5 - 9	97.5	99.2	99.8	100.0	100.0
10 - 14	96.7	99.1	99.7	100.0	100.0
15 - 19	94.3	98.6	99.6	100.0	100.0
20 - 24	88.2	97.4	99.1	100.0	100.0
25 - 29	85.1	96.9	98.7	99.9	100.0
30 - 34	76.6	95.9	98.3	99.9	100.0
35 - 39	60.4	90.6	95.7	99.9	100.0
40 - 44	50.8	83.3	91.2	99.5	99.9
45 - 49	36.4	73.2	85.2	98.5	99.9
50 - 54	21.2	61.5	77.2	95.7	99.9
55 - 59	17.4	46.6	61.0	90.4	98.6
60 - 64	7.7	31.1	44.4	80.2	94.8
65 - 69	3.4	17.7	28.0	69.4	86.2
70 - 74	1.8	10.1	18.2	55.6	74.3
75 - 79	0.2	8.2	14.8	50.8	65.7
80 - 84	0.2	2.1	8.7	28.2	58.1
85 - 89	0.2	0.6	2.4	16.8	45.6
90 - 94	0.0	0.0	0.0	10.9	45.6
95 - 100	0.0	0.0	0.0	0.0	45.6

This PPI was created in April 2016 using Rwanda's 2010/11 Integrated Household Living Standards Survey by Mark Schreiner of Microfinance Risk Management L.L.C., developer of the PPI. For more information, please visit www.progressoutofpoverty.org.

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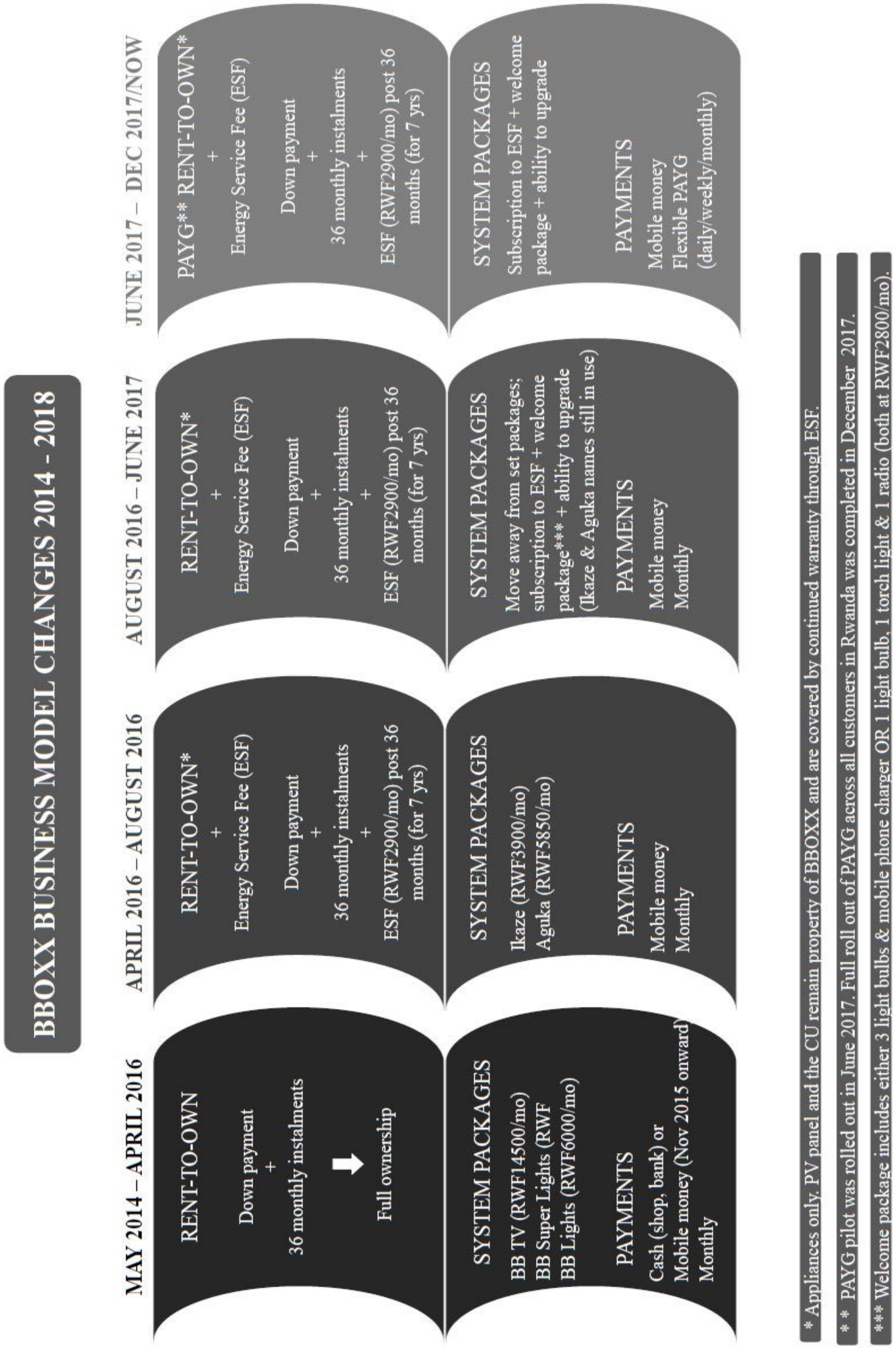
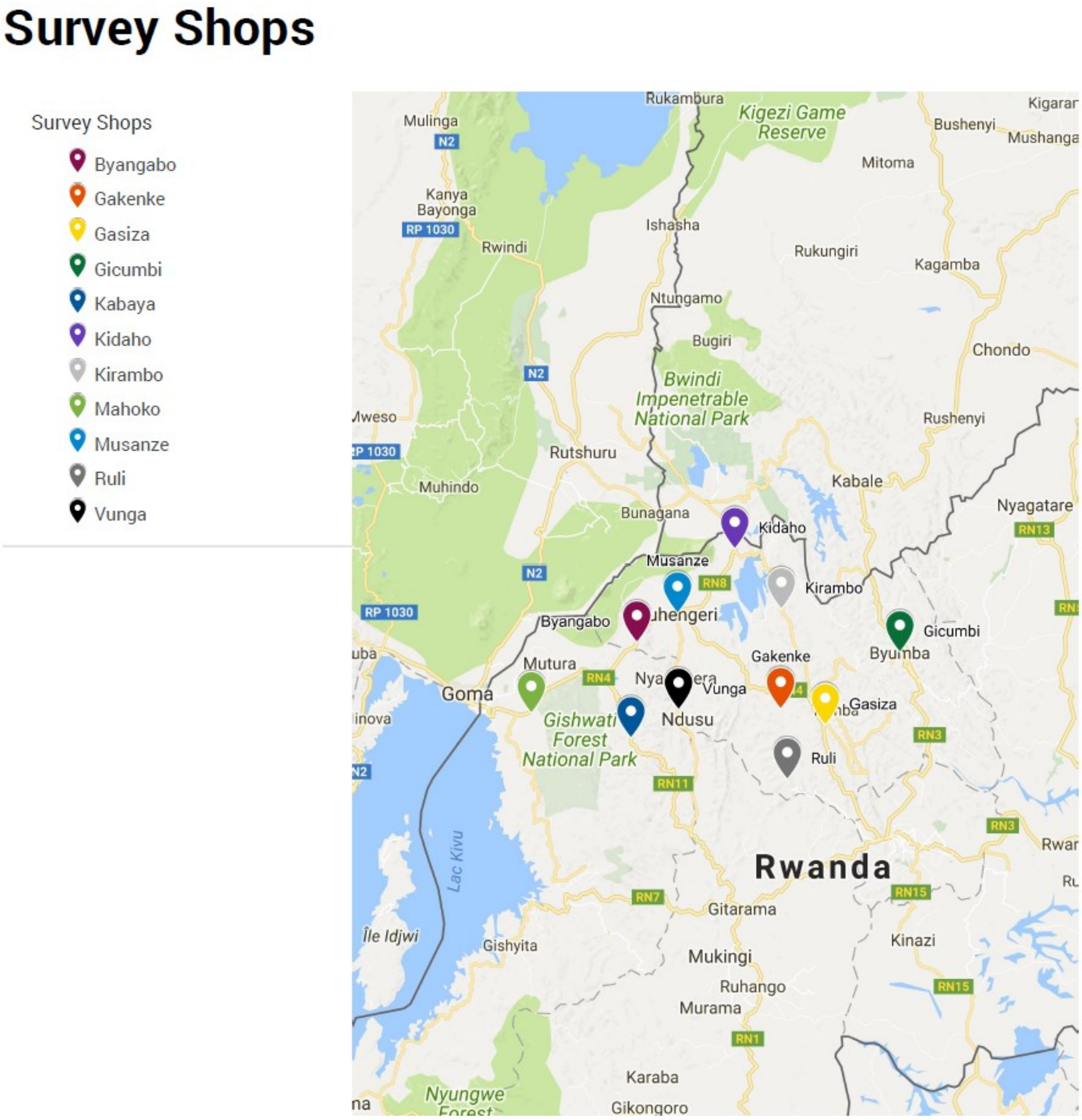
Appendix 11: BBOXX Business model and system package change timeline



Appendix 12: Map of BBOXX shops from which study customers have been sampled



Appendix 13: Ethical Approvals (UCL) and Research Permit (UR-CST and Rwanda Ministry of Education)

UCL RESEARCH ETHICS COMMITTEE
ACADEMIC SERVICES

UCL

21 June 2016

Dr Priti Parikh
Department of Civil, Environmental and Geomatic Engineering
UCL

Dear Dr Parikh

Notification of Ethical Approval
Re: Ethics Application 7445/002: Scaling up the solar energy revolution through remote monitoring and improved understanding of customers' energy use of decentralised (SMART) systems. A case study of BBOXX customers in Rwanda

I am pleased to confirm in my capacity as Chair of the UCL Research Ethics Committee (REC) that I have ethically approved your study for the duration of the project until 21st June 2017.

Approval is subject to the following conditions.

1. You must seek Chair's approval for proposed amendments to the research for which this approval has been given. Ethical approval is specific to this project and must not be treated as applicable to research of a similar nature. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing the 'Amendment Approval Request Form': http://ethics.grad.ucl.ac.uk/responsibilities.php

2. It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator (ethics@ucl.ac.uk) immediately the incident occurs. Where the adverse incident is unexpected and serious, the Chair or Vice-Chair will decide whether the study should be terminated pending the opinion of an independent expert. The adverse event will be considered at the next Committee meeting and a decision will be made on the need to change the information leaflet and/or study protocol.

3. For non-serious adverse events the Chair or Vice-Chair of the Ethics Committee should again be notified via the Ethics Committee Administrator (ethics@ucl.ac.uk) within ten days of an adverse incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Chair or Vice-Chair will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.

On completion of the research you must submit a brief report of your findings/concluding comments to the Committee, which includes in particular issues relating to the ethical implications of the research.

Yours sincerely

[redacted]

Professor John Foreman
Chair of the UCL Research Ethics Committee

Cc: Iwona Bisaga, Applicant

Academic Services, 1-19 Torrington Place (9th Floor),
University College London
Tel: +44 (0)20 3108 8216
Email: ethics@ucl.ac.uk
http://ethics.grad.ucl.ac.uk/

UCL RESEARCH ETHICS COMMITTEE
ACADEMIC SERVICES

18th September 2017

Dr Priti Parikh
Department of Civil, Environmental and Geomatic Engineeering
UCL

Dear Dr Parikh

Notification of Ethics Approval
Project ID/Title: 7445/003: Scaling up the solar energy revolution through improved understanding of customers' needs, aspirations and energy use of decentralised (SMART) solar home systems. A case study of BBOXX customers in Rwanda

I am pleased to confirm in my capacity as Joint Chair of the UCL Research Ethics Committee (REC) that I have ethically approved the data collection phase of the study until **27th September 2018**. Ethical approval is not required for the subsequent data analysis or publication of the results.

Approval is subject to the following conditions:

Notification of Amendments to the Research
You must seek Chair's approval for proposed amendments (to include extensions to the duration of the project) to the research for which this approval has been given. Ethical approval is specific to this project and must not be treated as applicable to research of a similar nature. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing an 'Amendment Approval Request Form'
http://ethics.grad.ucl.ac.uk/responsibilities.php

Adverse Event Reporting – Serious and Non-Serious
It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator (ethics@ucl.ac.uk) immediately the incident occurs. Where the adverse incident is unexpected and serious, the Joint Chairs will decide whether the study should be terminated pending the opinion of an independent expert. For non-serious adverse events the Joint Chairs of the Ethics Committee should again be notified via the Ethics Committee Administrator within ten days of the incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Joint Chairs will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.

Final Report
At the end of the data collection element of your research we ask that you submit a very brief report (1-2 paragraphs will suffice) which includes in particular issues relating to the ethical implications of the research i.e. issues obtaining consent, participants withdrawing from the research, confidentiality, protection of participants from physical and mental harm etc.

Office of the Vice-Provost Research, 2 Taviton Street,
University College London
Tel: +44 (0)20 7679 8717
Email: ethics@ucl.ac.uk
http://ethics.grad.ucl.ac.uk/

REPUBLIC OF RWANDA

[redacted]

MINISTRY OF EDUCATION
P.O.BOX 622 KIGALI

Re: Permission to Carry out Research in Rwanda - No: MINEDUC/S&T/379/2016

The Permission is hereby granted to **Ms. Iwona Magdalena Bisaga,** Ph.D student at the University College London, United Kingdom and **Iradukunda Christian** and **Uwase Marceline**, Research assistants, to carry out research on: **"Scaling Up the Solar Energy Revolution through Remote Monitoring and Improved Understanding of Customers' Energy Use of Decentralized (SMART) Systems a Case Study of BBOXX Customers in Rwanda".**

The research will be carried out in various districts where BBOXX customers are located. Researchers will need documents about rural electrification plans. They will need to interview officials from the Ministry of Infrastructure especially those working in the field of energy. They will need also to interview selected customers of BBOXX using Solar Home Systems.

The period of research is from **10th August, 2016 to 09th August, 2017**. It may be renewed if necessary, in which case a new permission will be sought by the researchers.

Please allow the **above mentioned researchers**, any help and support they might require to conduct this research.

Yours sincerely,

[redacted]

Marie-[redacted]
Director General of Science, Technology and Research

REPUBLIC OF RWANDA

[redacted]

MINISTRY OF EDUCATION
P.O.BOX 622 KIGALI

Re: Extension of Permission to Carry out Research in Rwanda

The Permission is hereby granted to **Ms. Iwona Magdalena Bisaga,** Ph.D student at the University College London, United Kingdom and **Iradukunda Christian** and **Uwase Marceline,** Research assistants, to continue the research on: **"Scaling Up the Solar Energy Revolution through Remote Monitoring and Improved Understanding of Customers' Energy Use of Decentralized (SMART) Systems a Case Study of BBOXX Customers in Rwanda".**

The period of research is from **18th September 2017 to 30th April 2018**. It will continue to be carried out in various districts where BBOXX customers are located under affiliation of the University of Rwanda-College of Science and Technology (UR-CST) under supervision of **Prof. Santhil Kumaran,** Department of Civil, Environment and Geometric Engineering, UR-CST.

The reference number of this letter shall be cited in the final research report as "Research conducted under permission No: **"MINEDUC/S&T/379/2016".** You are requested to submit the final report after completion of your research activities to the Ministry of Education of Rwanda

Please provide **the above mentioned researchers** any support they might require in the course of conducting this research.

Yours sincerely, [redacted]

Marie-Christine GASINGIRWA, Ph.D
Director General of Science, Technology and Research

Appendix 15: 'Off-Grid Solar in Rwanda: The way forward' Seminar

28.10.2016

OFF-GRID SOLAR IN RWANDA: THE WAY FORWARD

An event organised by UR College of Science and Technology, University College London & BBOXX

WHERE: UR-CST KIST 2 Building Top Floor TIME: 9^{00}-12^{30}, Fri 28th

We have a pleasure to invite you to this jointly organised event which aims to bring together key stakeholders working in the field of off-grid solar in Rwanda, both in the public and the private sphere.

Talks and discussions include:

- The state of off-grid solar and where it is going next, particularly in the context of Rwanda's Rural Electrification Strategy & Campaign
- Presentations from key private providers of off-grid solar operating in the country
- Existing initiatives supporting the off-grid solar sector, such as Energising Development
- Current research focusing on off-grid solar, with the presentation of a PhD-level collaborative research of UR-CST-UCL-BBOXX

Professor Manasse Mbonye, the Principal of UR-CST, will open the event.

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Why attend?

Confirmed participation by some of the key sector stakeholders in Rwanda

Space for discussion on the future of off-grid solar solutions in Rwanda's energy mix

Opportunities for new research and collaborative partnerships

Refreshments provided!

Let's talk off-grid solar

TO CONFIRM ATTENDANCE EMAIL:
Iwona Bisaga
i.bisaga.12@ucl.ac.uk

	Off-Grid Solar Seminar: The Role of Off-Grid Solar in Rwanda's Energy Mix Going Forward
	28/10/2016
	UR-CST Building 2, Top Floor
9:00 - 9:30	Registration (coffee & breakfast snacks)
9:30 - 9:40	**Welcome by the Principal - Professor Manasse Mbonye**
9:40-10:05	**Presentation 1: BBOXX (Laurent van Houcke/Justus Mucyo)**
10:05 - 10:30	**Presentation 2: Energising Development/GIZ (Simon Rolland)**
10:30 - 10:55	**Presentation 3: EDCL (Morris Kayitare)**
10:55 - 11:15	**Presentation 4: UCL-BBOXX-UR-CST Research (Iwona Bisaga)**
11:15-11:30	Break
11:30-12:30	**Panel Discussion**
12:30	Seminar Close & Light Lunch

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Appendix 16: 'Social Research in Off-Grid Solar' Conference

SOCIAL RESEARCH ON OFF-GRID SOLAR

A two-day conference organised by University College London and the University of Edinburgh.

Programme and speakers

9-10th December 2015

University College London, WC1E 6BT

CONFERENCE PROGRAMME

DAY ONE – WEDNESDAY 9TH DECEMBER

9.30 Registration & Coffee

10.00 Welcome

10.15 Session 1: Business & Technology Design

Keynote: Dr Robert Byrne (University of Sussex) *Beyond financing technology: international policy ambitions, pay-as-you-go sustainable energy access and theories of social change*

Tea & Coffee

Nathan Holford (BBOXX) *BBOXX SMART Solar: Opportunities and Challenges*
Lukas Lukoschek (MeshPower) *Designing impact-oriented rural services*
Tim Young (Practical Action) *Access to energy services: key issues around off-grid solutions*

12.30 Lunch & Poster Exhibition

13.30 Session 2: User Interaction & Experience

Iwona Bisaga (UCL) *After-sales services: the role of human-centred design*

Anya Boyd (Engineers without Borders UK) *Engineers without Borders UK and its involvement in off-grid solar in East Africa and Peru*

Kirsten Campbell (University of Edinburgh) *The Development of the Off- Grid Renewable Energy Sector in India: A User Perspective*

Declan Murray (University of Edinburgh) *Kenya's solar markets and what they mean for the end user*

Tea & Coffee

15.15 Session 3: Effects & impacts

Keynote: Kat Harrison (SolarAid) *Knowledge, learning and research on the impact of off-grid solar energy access*
Vijay Bhopal (SCENE Consulting) *Stoves and Mirrors: How technology is being utilised to monitor the true impacts of off-grid solar*
Karima Hirji (HEDON Network) *Decentralised solar energy: Shedding light on benefits for people and the planet*
Peter Thomas (Centre for Alternative Technology) *Energy: The Humanitarian Context*

17.15 Close

18.00 Dinner at Olivelli Restaurant, Store Street, WC1E 7BS

DAY TWO – THURSDAY 10TH DECEMBER

9.30 Registration & Coffee

10.00 Welcome

10.15 **Session 4: The role of policy**

Keynote: Alistair Wray (DFID) *The Role of Policy in Unlocking the Potential for Decentralised Clean Energy* & Dr. Ryan Hogarth (ODI) *The role of policy in the diffusion of off-grid solar*

Tea & Coffee

Dr. Xavier Lemaire (UCL) *Can policies support off-grid solar? An organisational perspective*
Rebecca Mawhood (Imperial College London) *Institutional barriers to a 'perfect' policy: A case study of the Senegalese Rural Electrification Plan*
Dr. Michael Price (Smart Villages Initiative, University of Cambridge) *The Future of Off-Grid Living for the Developing World: The Smart Villages Approach*

12.30 Lunch & Poster Exhibition

13.30 **Session 5: The past and the future**

Keynote: Dr. Jamie Cross (University of Edinburgh)
Dr. Chris Emmott (Imperial College London) *Can off-grid solar provide a climate friendly future?*
Philip Sandwell (Imperial College London) *Off-grid solar photovoltaic systems for rural electrification and emissions mitigation in India*
Amro Tabari (Mott MacDonald) *Sustainable Off-Grid PV systems*

15.15 Tea & Coffee

17.00 **Session 6: Conference summary**

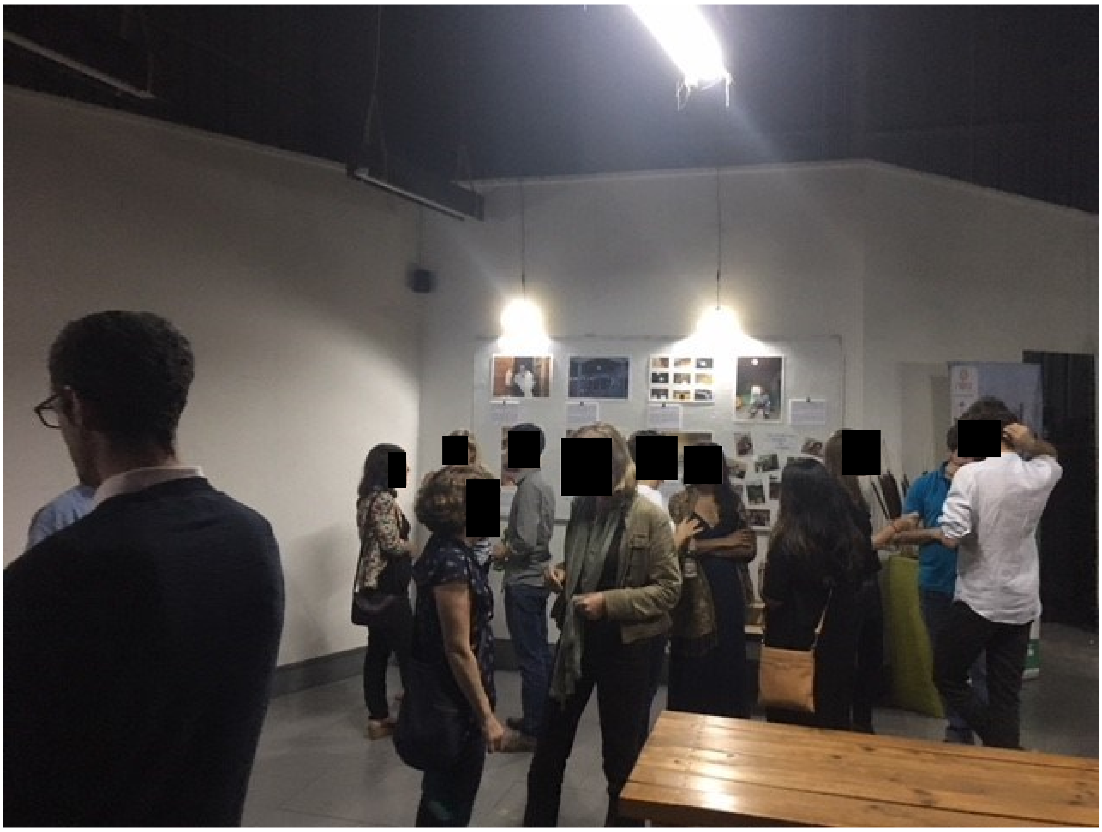
Chair: Dr. Xavier Lemaire (UCL)

Dr. Jamie Cross (University of Edinburgh)
Kat Harrison (SolarAid)
Dr. Rob Byrne (Sussex University)
Alistair Wray (DFID)
Dr. Ryan Hogarth (ODI)

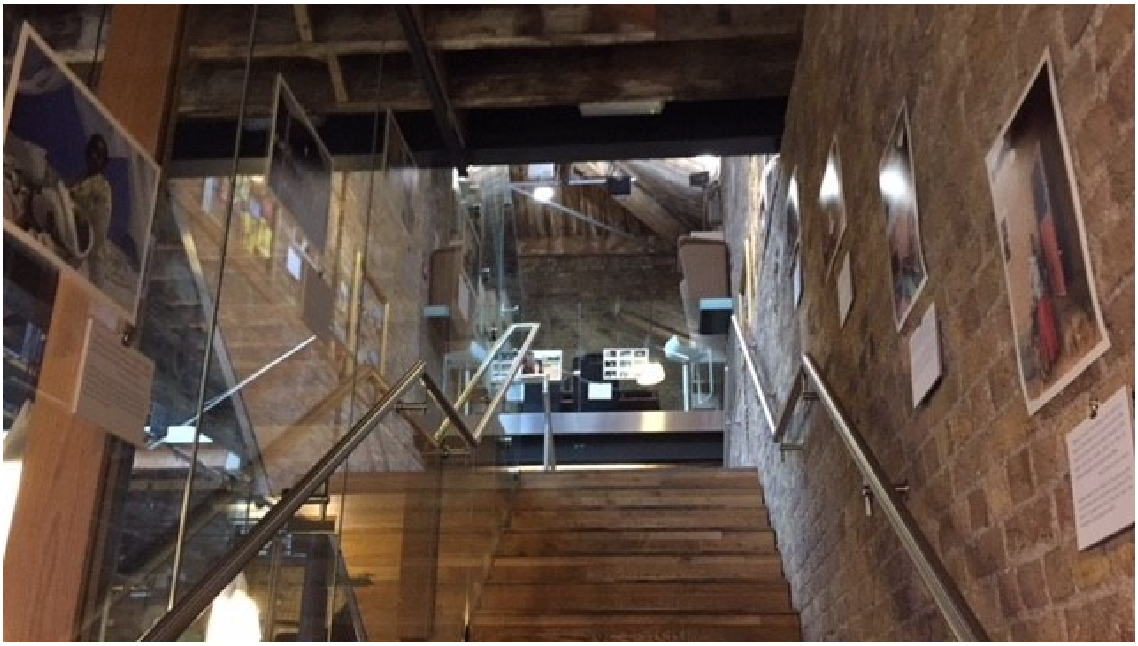
Close

Appendix 17: 'Through the Lens' Photography Exhibition: Kigali & London flyers and photos

Photos Credit: I. Bisaga.



Photos Credit: I. Bisaga.



Photos Credit: I. Bisaga.