Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP)

IMPACT ASSESSMENT OF THE SOLAR ELECTRIFICATION OF MICRO ENTERPRISES, HOUSEHOLDS AND THE DEVELOPMENT OF THE RURAL SOLAR MARKET

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EXECUTIVE SUMMARY

The use of Solar Home Systems (SHS) is widely seen as a contribution to poverty alleviation and recommended as a sustainable source of modern energy for rural areas in developing countries. In order to disseminate solar systems to households and micro enterprises, market based approaches to build up rural distribution structures for solar PV are increasingly seen as a more viable alternative to subsidised government or international donor projects. This paper studies the socio-economic and productive impacts of Solar Home Systems on households and micro enterprises as well as the impact of the support of the activities of the Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP) on the development of rural solar markets in Uganda.

It was found that market based approaches to disseminate SHS favour the upper class of better educated and wealthier households and enterprises which mainly use the solar systems for lighting. Although there is little impact on poverty alleviation and the MDGs, some possible long term impacts on education through longer hours of studying and reading in the evenings were found. After 2 years of use of the SHS, it was found that households and enterprises did not climb the energy ladder but continue to use traditional forms of energy alongside solar PV. Due to unexpectedly high expenditures on replacements for blown out bulbs total energy expenditures are not reduced. While no increased income generating activities were found in households, solar light leads to longer hours of operation and higher profits in existing micro enterprises. Nevertheless the net impact of longer opening hours on the local economy is negligible as the demand for existing products is saturated and smaller enterprises without solar light are crowded out. In contrast new businesses which are enabled through solar PV - notably phone charging and electric hair cutting - tap an unsatisfied demand diversifying the local economy. The development of rural solar markets has positive net employment effects. A 1% coverage rate of SHS leads to 0,02% newly created “green jobs”.

In order to increase the impact of GTZ support, it is recommended to adapt a “social market approach” which targets farmers - the “bottom of the pyramid” - and smaller systems. This social approach should comprise “complementary awareness and training services” to improve access to solar PV for the poor, bring down energy expenditures and to foster the productive income generating use of solar. The best practice was found to be the support of a “tripartite solar supply structure” with specialized actors in charge of mobilization, financing and installation with clear duties and responsibilities. This market performs better if actors build a local and physical sales and service infrastructure. It is further recommended to adapt a holistic “energy approach” which combines and uses synergies of solar and improved stove market promotions so as to simultaneously address the high expenditures on biomass energy and indoor air pollution related diseases notably for women.

ABBREVIATIONS AND ACCRONYMNS

ERT	-	Energy for Rural Transformation
MDI	-	Micro Deposit-taking Institution
MFI	-	Micro Finance Institution
PPP	-	Public Private Partnership
PREEEP	-	Promotion of Renewable Energy and Energy Efficiency Programme
PV	-	Photovoltaic
REA	-	Rural Electrification Agency
SACCO	-	Savings and Credit Cooperative Organization
SEU	-	Solar Energy Uganda
SHS	-	Solar Home System
SME	-	Small and Medium Enterprises
UGX	-	Uganda Shillings
UNDP	-	United Nations Development Programme
UNEP	-	United Nations Environmental Programme
UPPPRE	-	Uganda Photovoltaic Pilot Project for Rural Electrification
Wp	-	Watt peak

1.0 INTRODUCTION

The Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP) , a joint project of the Ministry of Energy and Mineral Development (MEMD) and German Technical Cooperation (GTZ), seeks to promote access to modern and sustainable energy services by the Ugandan poor. The PREEEP activities, which mainly focus on energy policy, energy efficiency, dissemination of efficient biomass technologies and rural electrification, are aimed at provision of better energy services for social and economic development.

This report assesses the impact of PREEEP's activities to support the dissemination of Solar Home System (SHS) for the electrification of (i) microenterprises and (ii) households as well as (iii) the development of rural markets for solar PV. The assessment was conducted more than three years after the start of PREEEP's technical assistance in the development of rural markets for solar PV, working in partnership with Solar Energy Uganda (SEU), Incafex Solar Systems and UltraTec/ Nacosolar among others.

1.1 Background of PREEE Programme

The overall goal of PREEEP is improved access to modern energy services. The Photovoltaic (PV) component of the program focuses on access to PV systems for households, institutions (notably Health Centres) and Microenterprises. The overall program strategy is the creation and support of rural market dynamics. The implementation of the strategy commenced with the development of sustainable solar business models that are implemented in the framework of Public Private Partnership (PPP) contracts. Accordingly, the first phase consisted of the establishment of PPPs between GTZ and solar companies and ran from March 2006 to October 2008. The second phase is currently ongoing and is expected to conclude in 2012.

The PPP contracts were established with market players in the PV industry with years of experience, good reputation, capacity and motivation to drive market development,

up scaling and replication. The contracts, which were set up with three major solar companies [Solar Energy Uganda, Ultra Tec/ Nacosolar and Incafex], focus on market development activities. Under the contracts, PREEEP funds up to 50% of the costs of penetration and establishment of rural markets for solar PV products. The supported activities under the program include business and technical training for local partners and technicians, promotional activities such as radio advertisements, brochures and demonstration kits as well as support for the cooperation with microfinance institutions. Although the nature of PREEEP's support has been similar for all companies, each of the three companies established a unique market business model.

In the original target areas of Rakai, Masaka and Bushenyi; the solar market could be characterized as a marginally tested market where some project based efforts had been implemented[1]. At the time of the inception mission, however, the activity level was found to be insignificant in these areas. Although a sizeable sector of Kampala based solar companies existed, they were mostly engaged in larger system installations (schools, health centers etc.), and power back-up systems.

Despite many years of support by UNDP/UPPRE and World Bank/ERT (Energy for Rural Transformation) to develop the rural solar home system market, such activities were an almost negligent part of the portfolio of the solar companies at the start of the project. It can even be concluded that the heavy presence of these donor projects had resulted in (i) the solar companies taking a back seat in market development serving only lucrative markets and donor projects, as well as it resulted (ii) an almost complete lack of sustainability in rural solar entrepreneurship. In the mean time, experiences in neighboring countries (Tanzania and Kenya) had demonstrated a self-sustaining rural solar market development based on rural entrepreneurship.

Among the Kampala based companies however, there was still a pending interest to follow up on the development of rural markets in these pilot project areas. GTZ concluded that PPPs with some of the major Kampala based solar companies

[1] In Rakai, a UNEP project has supported some training and one community solar project. In Masaka, Shell Foundation had supported the development of a franchise concept for Ultratec, while in Bushenyi, "Stitching De Oude Beuk" had supported a pilot project of SHS micro financing. In Namulonge, a small number of solar-powered LED lighting systems had been installed with subsidies from GTZ.

(Incafex, SEU and Ultratec) would be the key entry point to a more sustainable solar market development.

1.2 Objectives of the Impact Assessment

The term "Impact Assessment" has been used to highlight the scientific methodological approach with which we attempt to compare the project's results with a counterfactual. The assessment findings however reveal that the majority of microenterprises and households with SHSs in the PREEEP access region (represented by 75% and 83% respectively) have used solar products for less than two years. As such, an assessment of impacts of the SHSs on the users could be viewed as untimely at this stage. In terms of interpretation, it would thus be more appropriate to refer to the underlying study as a 'Tracer Study', tracking the progress towards the achievement of the PREEEP objectives for microenterprises and households. It also attempts to project the likely direction of the impact of the program on the intended beneficiaries**.**

The purpose of the 'Impact Assessment' or better 'Tracer Study' is threefold:

1) To assess the impact of solar home systems on the performance of microenterprises, with a focus on the "use" of solar products for productive purposes;
2) To assess the impact of the "use" of solar home systems on the socio-economic living conditions of households; and
3) To evaluate the effect of the GTZ PREEEP on rural solar markets, focusing on "access" of microenterprises and households to solar products.

2.0 METHODOLOGY OF THE ASSESSMENT

The methodology adopted for the study is a cross sectional analysis which is intended to identify causal effects of access to and use of SHSs by firms and households. Firms and households with and without access to SHSs as well as users and non-users are compared. To this end, 6 sub counties that are covered by the PREEEP supported companies in the three districts (Rakai, Masaka and Bushenyi) were surveyed and are hereafter referred to as the treatment group. For comparison purposes, 6 other sub counties not covered by the supported solar companies were surveyed within the same districts. The latter 6 sub counties form the control group.

In order to avoid heterogeneity in variables across the selected locations- that could possibly influence the findings- the key characteristics for selecting the sub counties to be included in the sample are as follows (*details in Appendix I*):

- Geographic location: The locations are the three districts of Rakai, Masaka and Bushenyi, all in the same region of South Western Uganda.
- Road access: Asphalt or dirt roads conductible in dry and wet seasons by cars and lorries.
- Population: Comparable sub counties with a population of 3,000 to 9,000 households.
- Educational institutions: Presence of primary, secondary and vocational/ technical schools in each sub county.
- Economic relevance: Existence of medium size trading centers with 30-150 microenterprises.
- Main economic activity: Agriculture- mainly cultivation of food crops and cash crops (coffee and tea) on a small scale.
- Industry: Small scale agro-processing such as maize milling, tea processing and coffee hurling.
- Health care: Existence of health centres, small clinics and pharmacies.
- Financial institutions: Existence of microfinance institutions/ SACCOs that provide credit and other financial services.

All the above factors were considered in the selection of the treatment and control locations, with the only visible difference being enterprise and household access to solar companies that are supported by PREEEP. In addition, consultations were made with District Planners and Statisticians of the three districts to obtain a general overview of the economic conditions in the respective districts. This was done to ensure the selection of appropriate survey locations that were comparable in all the above respects.

Microenterprise Survey

All the sampled enterprises comprise firms that are located in permanent structures (either as part of the household's premises or independent). In total, 104 enterprises were interviewed, 62 of which are located in sub counties covered by the GTZ PREEEP and 42 in the non served sub-counties as illustrated in the table below.

Table 1: Summary of sampled microenterprises

Sector	Type of enterprises	Enterprises without access to local PV markets and solar companies	Enterprises with access to local PV markets and solar companies	Total
Artisan	(Carpentry, welding, mechanics, tailoring, saw mills)	8	6	14
Service	(Restaurants, bars, shops, hair salons, phone charging, stationery, photo studios, electrical shops)	30	54	84
Agriculture	(Cereal mills, vegetable mills)	4	2	6
Total		42	62	104

Analyzing the performance, it turns out that the profits of enterprises that invested in SHSs (users) are five times higher than those that did not (non users). Given that the better performance of enterprises is not necessarily due to the use of solar energy but the fact that already at the outset only the wealthier enterprises undertake the investment, it was determined that comparing all users to non-users would lead to a selection bias. Accordingly, an appropriate comparable group of enterprises has been identified through matching, which was done according to the type of business and level of education of the owner. Apart from the economic sector, the level of

education was found to be an ideal matching variable, since it is constant irrespective of whether a SHS is used or not and correlates with profits. It is also a decisive factor of whether an owner decides to purchase a SHS. Hence, if in the non access region SHSs do become available, it is more likely that more of the non users with at least some level of formal education will purchase one.

In controlling for these variables, we attempt to prove causality between the use of solar energy and firm performance. Consequently, data analysis will further focus on a sub-sample of 41 service enterprises with and without solar, of which the owner has primary level of education. In order to further increase the comparability, the profit section will focus on a sub sample of 30% of the least performing enterprises which have profits of less than half a million Uganda Shillings (UGX)[2]. This is intended to give an estimation of the monthly value added of a SHS. Comparisons have been made to assess various aspects including occupation, income/turnover, expenditure, investment/capital endowment, market access and access to finance as described in the relevant sub sections that follow.

Household Survey

Considering the small sample size and low take up rate of solar PV, it was not possible to apply random sampling in the access region so as to provide enough information on the SHS users. In the selection of household survey locations, customer lists generated from the three GTZ supported solar companies were used to identify SHS users who directly benefited from the program. Additionally, other SHS users within the program access region were interviewed to generate adequate responses about the impact of solar PV. The criterion for household selection was based on the length of ownership and use of the SHS, with priority being placed on SHS owners of 2 years and above (where possible).

A total of 292 households were sampled, 170 of which are in sub counties covered by the GTZ supported solar companies, while 122 are in non access sub counties as summarized in table 2 below.

[2] About USD 240 (exchange rate of 16th April 2010: 1 USD = 2,080 UGX).

Table 2: Summary of sampled households

		Village not covered by GTZ SHS program	Village covered by GTZ SHS program	Total
SHS use	Non use	111	35	146
	Use	11	135	146
Total		122	170	292

Comparing the selected users in the access region to the randomly selected non users in the non access region would lead to a serious bias, as again mostly the wealthier and better educated households are overrepresented in the sample of SHS users. In order to reduce the bias, matching was applied to only households with secondary and tertiary level of education and an arable land size of less than 11 acres. It was found that households with higher levels of education are benefiting more from solar systems notably for reading and studying in the evening, hence are more likely to invest in solar PV.

Since all households are engaged in agriculture, large scale farmers were excluded, as no comparable households were found among the randomly selected non-users. Accordingly, the main impact sections focus only on the matched sub sample of 110 households. Considering that this matched sample has a slightly higher percentage of private sector employees, government workers and traders using solar systems, further matching was done comparing only farmers.

Solar Market

In order to assess the GTZ support with regard to its final aim of developing a rural solar PV market, interviews were held with area managers of the three through PPP supported solar companies. The interviews sought to establish the current status of the solar market, availability of solar systems, the nature of GTZ support received in relation to its relevance and effectiveness, challenges faced and potential long term trends in market development among others. Furthermore, Financial Extension

Workers (FEWs)[3] of the three districts as well as managers of locally based financial institutions were interviewed in both the treatment and control regions to establish the coverage and finance options for solar systems.

The aim of studying the creation and support of rural market dynamics by GTZ is to find out how developed the solar market would have been if the GTZ project had not been implemented, hence to determine the counterfactual. In doing so, the study assesses and compares the approaches of the three different solar companies that were supported through the PPPs in order to derive conclusions on their sustainability and performance. Recommendations on best practices on how to support the development of rural solar markets are given.

In this study, the number of installed systems, active local solar companies and solar technicians in the *treatment region* (where the development of the solar market was supported by the GTZ) will be compared to a *control region* (where GTZ has not been supporting the development of a solar market). The same analysis will be done for financial institutions providing solar loans, the current number of annual installations and the expected installations for the coming year. Further, as the solar market was quasi inexistent at project start an overtime comparison of the current state of the solar market completes the analysis.

Although the comparison of treatment and control regions allows some conclusions, it is difficult to determine the impacts of the GTZ project on the solar market since the GTZ supported solar companies were already the three major market players - at least in Kampala - before project start. Accordingly the counterfactual can only be observed to a limited extent. Further, since some of the three companies had been supported by other international donors, it is impossible to completely isolate the GTZ assistance and derive conclusions on the GTZ impact separately. While in consequence the following conclusions consider the GTZ and the international donor support as one, the findings on how conducive the support has been to develop the rural solar market have to be seen in light of these considerations.

[3] FEWs are individuals employed by the Ministry of Finance, Planning and Economic Development to disemminate financial information to rural communities on the rights of borrowing; saving culture and investment decision making.

2.1 Practical Survey Approach

The survey was conducted in 8 days by well trained enumerators under the close supervision of the consultants. Prior to data collection, it was ensured that the enumerators understood the intention of the study and each question. Accordingly, the enumerators were guided on the proper administration of the questionnaires and good interviewing principles. At the end of each field day, questionnaires were checked for completeness and accuracy, and missing or incoherent information was corrected by revisiting the respective respondents.

2.2 Assessment Indicators- Microenterprises

In order to assess the impacts of solar PV on firm performance, variables for "access to solar" and "use of solar", profit, capital, labour time, and use of lumen hours were created and defined as follows:

Profit is defined as the income that accrues to the business owner (in UGX) which is determined by the information from the owner. Thus the analysis concerning the enterprise performance needs to be interpreted with caution. Since all the microenterprises are owned by individuals, the profit represents the income. This is because small entrepreneurs in Uganda rarely distinguish between "private" and "business" capital and expenditure, thereby making it unsuitable to define profits in strict accounting terms.

Capital is defined as the aggregate value (in UGX) of the stock controlled by the enterprise. To draw a conclusion on how the capital might change after the enterprise has purchased a SHS, we distinguish between investments that were made before and after the purchase of the SHS.

Labour time is defined as total working hours per month and is obtained by multiplying the total number of workers by the average hours worked per day and the average number of days worked in a month.

In order to allow for a sectoral analysis that differentiates between enterprises that were created following the local access to solar electricity and those that existed prior to gain access to solar electricity, the enterprises were classified into two: ex-ante enterprises (existed prior to a community accessing solar) and ex-post enterprises (created after the community gained access to solar electricity).

Considering that market access – to sell products or services - seems to be a hindering factor for economic development of rural areas, a special focus was laid on whether the enterprise has access to local, regional, national and international markets.

A variable that calculates the total use of lumen[4] hours per month was also generated in order to examine the widespread hypothesis that the use of lumen hours – hence the amount of light used - is correlated with profits. Similarly, a variable was also created to examine whether the access to solar systems increases access to telecommunication.

2.2 Assessment Indicators Households

The assessment of the impact of SHS on households focused on the following indicators:

Employment/ occupation of households: By emphasizing on the kind of income generating activities that households are engaged in after sunset it is aimed to ascertain whether the use of solar PV influences productivity and incomes. Consideration is also made of the hours of activity per day by both male and female household members to determine whether access to solar facilitates longer hours of productive work.

Education: Comparisons are made between households with solar systems and those without to determine whether access to solar facilitates more enrollments in school and/or private study in the evenings as a result of access to better light. An analysis is

[4] Lumen hours is a unit used to measure the amount/quantity of light passing through a given area per second.

also made of other productive uses of solar electricity such as powering electric appliances with emphasis on whether access to solar influences interest in listening to or watching educative media programs.

Health aspects are also considered. Households with solar systems are compared to those without solar systems with regard to the incidences of respiratory tract infections from inhalation of indoor fumes, accidents from fires and eye related medical problems to determine whether the use of solar PV has an effect on health.

Environment: An analysis is made of the effect of the use of the different forms of energy by households on the environment with regard to pollution and carbon emissions.

Household living standards: The study also assesses the investment in electrical assets over time to determine whether the use of solar systems has any impact on households in this regard.

Energy sources used: Households were also asked about their consumption of different forms of energy and related expenditures to analyze whether SHS users climb the energy ladder[5] and/or switch from traditional to modern energy sources.

All the above mentioned variables are assessed in the relevant sections of this report.

2.3 Challenges Encountered

The following challenges were encountered during the execution of the assignment:

- Owing to the small sample size and the heterogeneity of microenterprises and households, data analysis of sub groups within the sample yielded varying

[5] Energy sources are classified according to their efficiency with electricity being the most efficient energy, followed by gas, kerosene, petrol, and biomass being the least efficient. Based on historical analysis - notably by analyzing the use of different energy sources in developed countries – it is observed that households and societies tend to switch to use higher efficient energies once they become available. This process is often described as climbing on the energy ladder: Once gas and electricity is available households tend to stop using kerosene light and biomass for cooking. Households climb the energy ladder.

results. The data should thus be interpreted with respect to these considerations.

- It was difficult to distinctly obtain comparable sub counties that were similar in all material respects. This was addressed by selecting locations that were closest to each other in terms of household population sizes and the level of socio-economic development.
- The enumerators met a few challenges in obtaining information from some respondents who feared that information was being gathered for tax assessment purposes.
- It was difficult to locate households and microenterprises that had acquired the solar systems from PREEEP supported companies in the selected sub counties, because they are scattered.

The above limitations notwithstanding, the consultants were able to obtain sufficient information to make meaningful analysis for the impact assessment.

3.0 ASSESSMENT FINDINGS - MICROENTERPISES

3.1 Enterprise Structure

A typical rural micro enterprise in Uganda is owned by an individual or household. The main objective of the business is to provide income to meet household needs including food, shelter, education, health and other family related expenses. A greater percentage of rural microenterprises in Uganda comprise of shops selling general merchandise- mainly basic household goods. Other enterprises include manufacturers (carpenters, auto, motorcycle and bicycle mechanics, forgers and electricians); service enterprises (lodges, restaurants, salons, pay telephones, phone charging and photo studios); and agro-based enterprises (grain mills, hurlers, produce stores) among others.

Rural microenterprises are largely run by self-employed people, employing up to three persons, who are mainly family members. The enterprises typically operate for 6 days a week and are open for about 11 hours from 08:00 hours to 19:00 hours, depending on the sector. Other enterprises- like bars and a few shops- are open up to midnight**.**

Microenterprises in Uganda are largely financed by own capital and are characterized by inadequate professional record keeping and discipline in business conduct. The main problems affecting rural microenterprises, irrespective of whether they use SHSs or not, are:

- Lack of demand, quoted as the main problem by more than 50% of all enterprises.
- Limited capital and access to trade and finance to expand and develop the enterprises.
- Too many household related expenses that deplete the business of working capital.

- Heavy competition brought about by a concentration of enterprises offering the same products and services, often with limited innovation.

Further, the assessment findings show that out of the 40 interviewed enterprises that use SHSs in the program access region, 45% had used SHS for more than 12 months and 48% had used SHS for less than one year with the majority (30%) having acquired SHSs within the last 6 months as shown in the table below:

Table 3: Period of use of SHS by enterprises in PREEEP access regions

Period (Months)		Frequency	Percent	Cumulative Percent
	Not sure	3	7.5	7.5
	Less than 6	12	30.0	37.5
	6 – 12	7	17.5	55.0
	13 – 18	9	22.5	77.5
	19 – 24	2	5.0	82.5
	More than 24	7	17.5	100.0
	Total	40	100.0	

This underscores the fact that real impacts cannot be proven within this study. The result needs to be interpreted in light of the short time period enterprises have made use of SHS.

Other key highlights about the sampled microenterprises are:

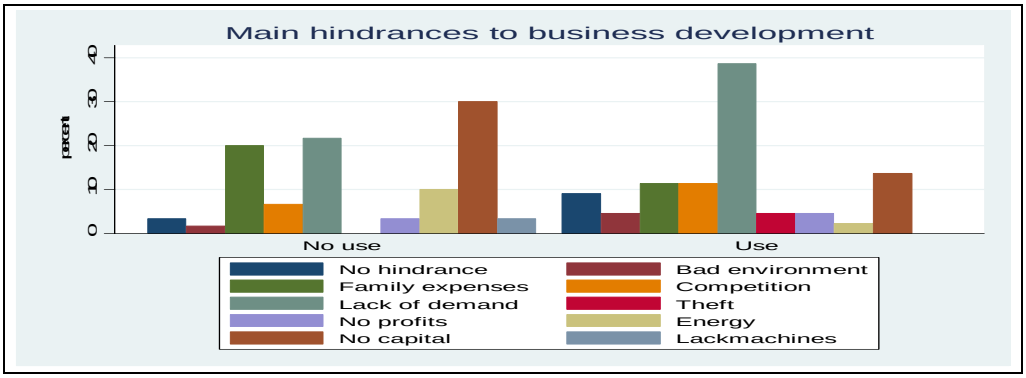
- 64 out of the 104 microenterprises (47% female) are owned/run by persons below the age of 35 years;
- 55% of the microenterprise owners (47% female) attended but did not complete primary school and 34% (31% female) attended but did not complete secondary school.
- 70 out of the 104 microenterprises (46% female) are micro enterprises employing up to 4 persons, while 13 (38% female) are self employed.

3.2 Main Hindrances to Business Development

Despite similarities concerning general problems that affect all enterprises, some interesting differences concerning the main hindrances to business development

between users of SHS and non users exist (see graph). While energy together with lack of appliances is seen as a main hindrance to development by 15% of non users, only 2% of SHS users mention it as a major hindrance. Interestingly while theft is not a problem in enterprises without solar systems it seems to be a problem for SHS users. The reason is, as will be demonstrated later, that the capital endowment is higher in enterprises using a SHS, which is also due to the value of the SHS. In consequence theft and notably theft of the solar panels is reported to be a problem. Further it is worth mentioning that 30% of the non users see the lack of capital as a main hindrance to development whereas only about 10% of the users consider it as a problem. The reason, as it will become clear later, is the higher share of SHS using businesses that make use of finance products. This is due to a higher financial awareness of SHS users which might be a consequence of the investment in a SHS which requires the use of financing products.

Figure 1: Main hindrances to business development



3.2 Take Up of Solar Systems

3.2.1 Investment in SHS - a Question of the Economic Sector

An impressing majority of 95% of the total installed SHS were found in the service sector, whereas the remaining 5% of SHS were found in the agricultural sector. No SHSs were found in the manufacturing sector. This is explained by the fact that the main use of solar energy among rural microenterprises is lighting. Service enterprises which typically include shops, bars and hair salons are open until late in the evening

as their services are mainly required after sunset when people have returned home from field work. This is often when household items are purchased from shops, people take drinks at the bar or have their hair styled.

In order to satisfy the evening demand, service enterprises with sufficient liquidity prolong their hours of operation with the use of kerosene or electric light. As electric light is typically not only much cheaper than kerosene light but much brighter and cleaner, it attracts more customers at night. It further allows hairdressers and health workers in clinics to perform their duties at night. This makes electric light an important value addition for service enterprises.

In contrast, manufacturing enterprises are run during day time. There is no need to light the business during normal hours of operation. One might argue that electric light enables them to augment their production, however since one of the main hindrances to rural business expansion and development is the lack of demand, it becomes clear that even if more was produced due to prolonged working hours in the evening, there would be no market for the products. Accordingly, manufacturers see no necessity to invest in solar energy since there is no value addition to their enterprises.

Although the agricultural sector in rural Africa is not electricity and lighting intensive, some solar application has been found, notably in the agricultural processing businesses and fish farming. Despite the agro-machinery being run by diesel, notably grain mills also operate in the evening and in consequence are in need of light. As agriculture is the backbone of the rural economy triggering the demand for agricultural processing, mills seem to be highly demanded. Accordingly, they are often run in the evening. In comparison to manufacturers, mills seem to be less demand restricted. Mills typically have the longest hours of operation due to the constant need of flour for cooking. Accordingly, millers are interested in solar energy to light their business to be able to work longer.

In conclusion, the findings indicate that manufacturers (carpenters, welders, mechanics and tailors) typically do not invest in SHS whereas service enterprises (shops, salons and bars) do. As shops are the most common businesses found in rural

villages, it is the type of business with the highest total number of installed SHSs. As illustrated in the table below, 57% of all investments in SHSs have been undertaken by shops, 16% by salons and 11% by bars and restaurants. Only a few investments in SHS represented by 2% have been undertaken by manufacturers/ agro-processors. Interestingly, it was found that 100% of the pharmacies/clinics invest in solar if available. Although pharmacies are few in rural villages, accounting for by 7% of the total number of installed SHS, they are likely to be fast movers once a village gains access to solar products. This seems to be related to the higher awareness of pharmacy/ clinic owners of the adverse hygiene and health effects of using kerosene lanterns.

Table 4: Summary of sampled enterprises that use SHS

Type of business		Frequency	SHS Use	Percent	Cumulative Percent
	Shop/Boutique	25	Lighting	56.8	56.8
	Bus link office	1	Lighting	2.3	59.1
	Bar/ lodge/ restaurant	5	Lighting/ TV/ phone charging	11.4	70.5
	Clinic/ pharmacy	3	Lighting	6.8	77.3
	Hair salon	7	Lighting, powering shavers and hair driers	15.9	93.2
	Payphone/ phone charging	1	Phone charging	2.3	95.5
	Grain mill/ produce store	1	Lighting	2.3	97.7
	Fish farm	1	Lighting	2.3	100.0
Total		44		100.0	

Emerging Enterprises Resulting from Investment in SHSs

As already mentioned, lighting is the main productive use of solar energy. Hence apart from longer hours of operation, not many options to become productive with solar energy were found. Further, typically rural enterprises are demand restricted so that even if machines/appliances could augment the production, products and services cannot be sold due to the lack of demand and saturation of local markets for existing products/services. Experience shows that to become productive with electricity and to use electric appliances in a profitable way one needs (i) to replace already used machines/appliances that are run by more expensive energy sources e.g. diesel/diesel generators or (ii) to offer new products or services that cannot be offered without

electricity and for which an untapped demand exist. Solar fridges, so as to offer cold drinks, ice cream or to stock other goods (e.g. fish), might be such a productive opportunity but was not found during the research.

Although electric light is the main purpose of solar energy, an increasingly growing phone charging business seems to emerge due to the availability of solar PV. This business replaces generator run phone charging businesses or substitutes "imported" phone charging from outside the region (i.e. in next grid-connected trading centre). The phone charging business is becoming more and more important as an increasing number of rural households use cell phones. Accordingly, a 100 Wp system which charges around 30 phones a day seems to tap full advantage of the capacity as local demand is unsatisfied. As charging one phone costs UGX 500, an entrepreneur might earn UGX 15,000 per day. Typically working at least 26 days a month, the monthly turnover is UGX 390,000 which is already one fifth of the total investment that can be estimated at UGX 2 million (for a complete system including an inverter). Due to the high investment costs, such a system is not in reach of many local entrepreneurs, but there are also smaller systems that cost UGX 800,000 and charge 6 phones a day. These kinds of businesses are increasingly interesting for local entrepreneurs after SHSs have become available in rural areas. Apart from the phone charging business, hair dressers are able to offer new products – due to solar energy - that satisfy an unsatisfied demand and hence become profitable. Through the use of electrical hair cutters, new types of haircuts can be offered. New clients are attracted and an unsatisfied demand can be tapped.

In line with economic theory, technical progress[6] enabled through the availability of solar energy- which allows one to offer new services - might enhance economic growth in rural areas. Hereby it is important to mention that the creation of the new businesses is not necessarily a win-win situation for the country as a whole since other businesses outside or even in the access region - that satisfied the demand before solar energy was available - might lose customers and in a worst case scenario have to close shop.

[6] Dosi, G. „Sources, Procedures, and Microeconomic Effects of Innovation." Journal of Economic Literature,1988, S.1120-1171

3.2.2 Investment in SHS - a Question of Performance

As highlighted in the methodology, the profits of the microenterprises that invested in a SHS in the access area are approximately five times higher than the profits made by randomly interviewed micro enterprises in the non access area. Given the recent use of the installed SHSs, it is unlikely that the reason is the better performance of the enterprises using solar energy, but rather the fact that from the outset, only the wealthier enterprises undertake the investment in SHSs. This is an important finding as it confirms the fact that market based approaches to development mainly benefit the wealthier social stratum.

In relation to microenterprises, this could also result in further disparities in performance, as the already financially sound enterprises are favored. Given that insufficient local demand is taken to be the main hindrance to business development and recognizing the fact that solar light enables enterprises to attract more clients, it can be concluded that the development of solar markets might lead to a concentration and selection process within the SME structure. This could mean that financially weak micro businesses (very small shops offering a small range of goods/ services) might close, losing their market share to the bigger and more successful ones.

By attracting more customers and through prolonged hours of operation, microenterprises with SHS may even cut their prices - due to economies of scale - and thereby making competition even stiffer. Whereas 10% of the enterprises in the access area reported high competition as the major business problem, it was only mentioned by 5% of the microenterprises in the non access region.

The process of uptake however seems to be slow as one can estimate that after two years of local availability of SHS, only 7%[7] of the service enterprises have decided to invest. As mentioned, these 7% represent only the better off as an investment in a small two light system already accounts for on average six months profits of rural service enterprises.

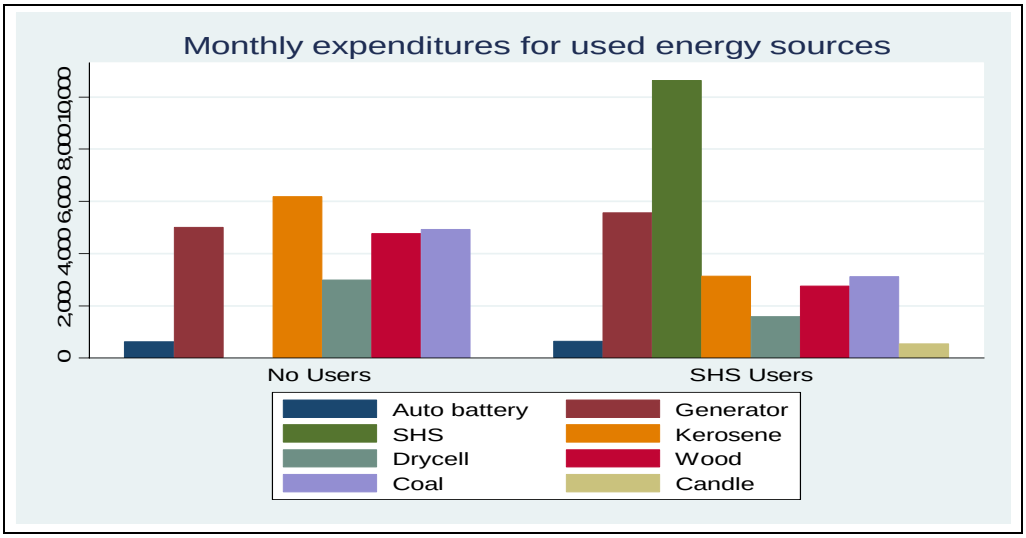
[7] Estimate generated from the coverage of microenterprises with solar systems in a sampled sub county (Kyalulangira- Rakai District) in the program access region.

3.3 Energy Expenditures and Use of Energy Sources

3.3.1 Energy Expenditures

Although it is widely believed that SHSs provide nearly cost free electric light once the investment is fully financed, the findings do not confirm this picture. Surprisingly, monthly expenditures for SHSs are the highest out of all energy sources of non users and SHS users. The initial investment costs and battery replacement costs are still excluded which would even increase monthly average expenditures on solar (see graph). SHS users have average monthly expenditures of about UGX 12,000 mainly on the replacement of blown out bulbs, whereas the highest expenditure for non users is kerosene, which is two times the amount spent by the SHS users on kerosene. Considering that a surprising 50% of SHS users regularly encounter technical problems - of which the majorities are blown out bulbs - and considering that a DC bulb costs about UGX 15,000, it becomes understandable that energy expenditures for solar light are high.[8] Taking into account that non electrified rural enterprises use artificial light for about 3 hours in the evening only - which does not cost more than UGX 6,000 for kerosene a month - it becomes obvious that solar light is only more cost effective than the use of kerosene light if high quality and longer lasting bulbs are used.

Figure 2: Monthly expenditures for used energy sources



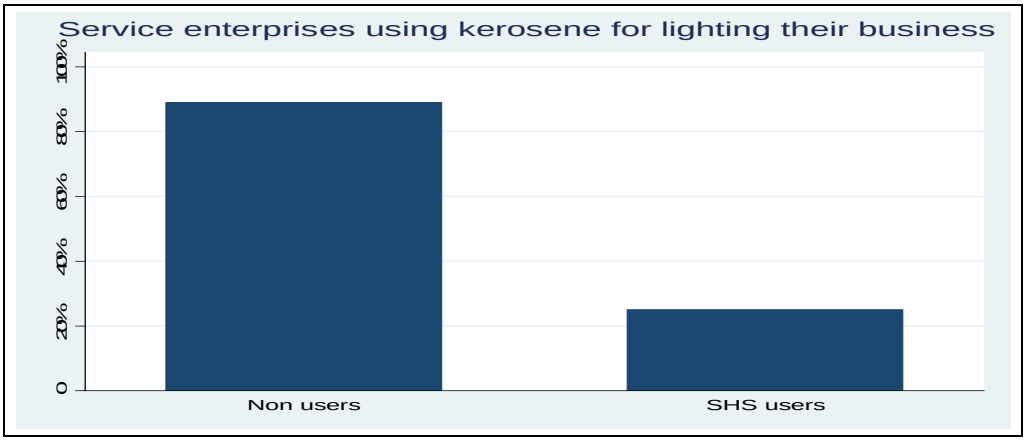
[8] This could be due to the use of low quality bulbs, technical problems of the system or misuse.

Accordingly, total energy expenditures (for SHS, kerosene, dry cells etc.) are slightly higher in enterprises using SHSs than in those without (UGX 27,500 vs. UGX 25,000 per month). This underscores the fact that SHS lead to additional energy costs. Nevertheless, in the long run, if traditional energy sources are replaced, SHS might reduce energy costs. One needs to note that most SHSs have been used for not longer than one year. As experience shows, it takes some time for SHS users to learn respect the system limits. Accordingly, failures, blow outs and maintenance costs might be reduced in the long run. Nevertheless the difference in monthly energy expenditures might not be that important even in the long run given that SHS users do not climb the energy ladder naturally but might continue to use a mix of energy sources as it will be explained in the following sections.

3.3.2 Use of Kerosene

Unlike the expectations, enterprises using a SHS do not completely switch from the lower efficient energy source to the higher efficient source once available. Although SHSs are able to provide more efficient and in the long run low cost electricity - if the systems perform well - enterprises do not climb the energy ladder naturally. Typically SHS users continue to use a mix of less and more efficient energy sources. Out of the SHS users interviewed, 25% still use kerosene whereas over 75% of the non users light their business with kerosene. While SHS users consume about 2 liters of kerosene a month, non users' consumption is nearly twice as much (about 3.5 liters). Accordingly it can be concluded that an investment in a solar system seems to lead to an important reduction of the use of traditional energy sources for lighting and notably of kerosene. However, enterprises continue to use a mix of energy sources and do not completely switch to the more efficient energy source once available (see graph).

Figure 3: Service enterprises using kerosene to light their businesses

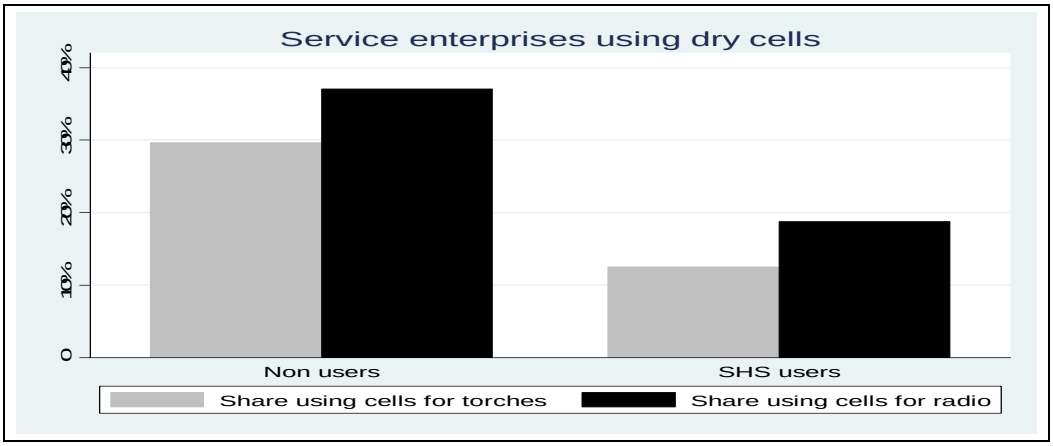


3.3.3 Use of Dry Cells

The use of dry cells for torches and radios shows a slighter difference between enterprises using SHSs and the ones not using when compared to the use of kerosene. Nevertheless a closer look sheds light on the fact that SHSs are of stationary nature, restricting the use of light to where the lighting applications are fixed whereas torches allow one to move outside and light a special spot (also the case in industrialized countries despite the wide availability of grid electricity). The same accounts for portable radios that can easily be transported and used in different locations using dry cells.

In addition, often existing radios have missing wiring or are not adapted to the DC current and voltage provided by SHS; while most of the systems installed in rural households are designed for lighting and phone charging only. In consequence nearly 40% of enterprises not using a SHS use 3 pairs of dry cells for radios a month whereas the share is cut by half for the SHS users (20%). Those use 2 pairs of dry cells a month. Concerning dry cells for torches, the picture is similar. It is likely that half of the SHS users' - who used about one pair a month before they installed the SHS - continue to use torches (on average little less than one pair a month) although electric solar light is available. To sum it up, concerning the use of dry cells one can roughly estimate that those using solar systems cut their use of dry cells by half due to the availability of solar current.

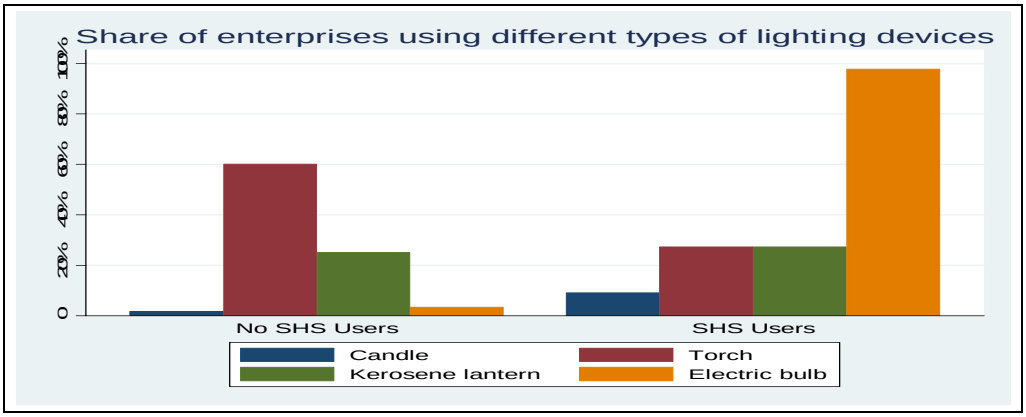
Figure 4: Service enterprises using dry cells



3.3.4 Use of Lighting Devices

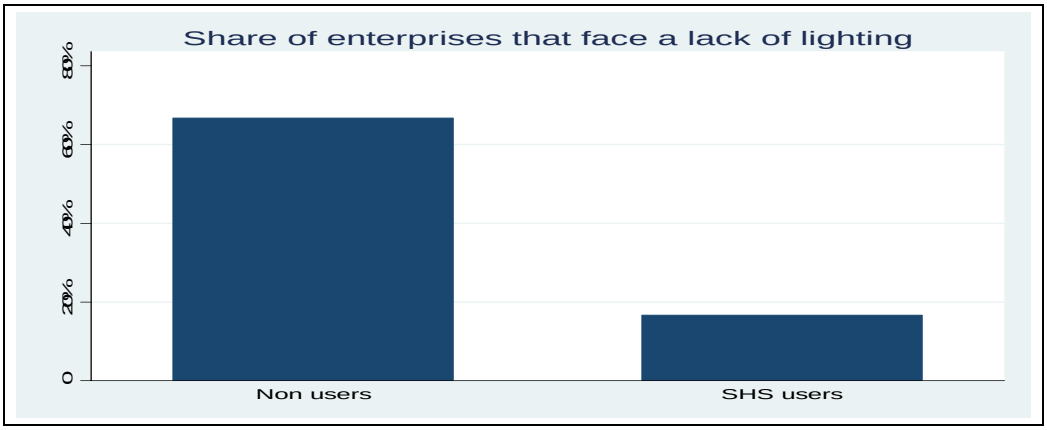
As already mentioned, enterprises which invested in a solar system do not naturally climb the energy ladder once they have purchased a SHS. Accordingly about 20% still use kerosene lanterns and torches regularly. The reasons for this are entrenched habits and customs and the stationary nature of the solar system in comparison to the portability of kerosene lanterns and torches. In addition, SHSs- if not working properly- are not cost effective due to blown out and expensive bulbs. One might bridge the time before the purchase of a blown out bulb with the use of kerosene. Nevertheless 100% of SHS make regular use of electric light partly replacing the use of kerosene lanterns. These are used by 60% of non-users (see graph).

Figure 5: Share of enterprises using different lighting devices



Overall the lighting situation seems to be improved due to solar light. Only a minority (less than 20%) of SHS users quote that there is a lack of lighting in their business whereas this is the case for over 60% of enterprises not using a SHS (see graph).

Figure 6: Share of enterprises that face a lack of lighting

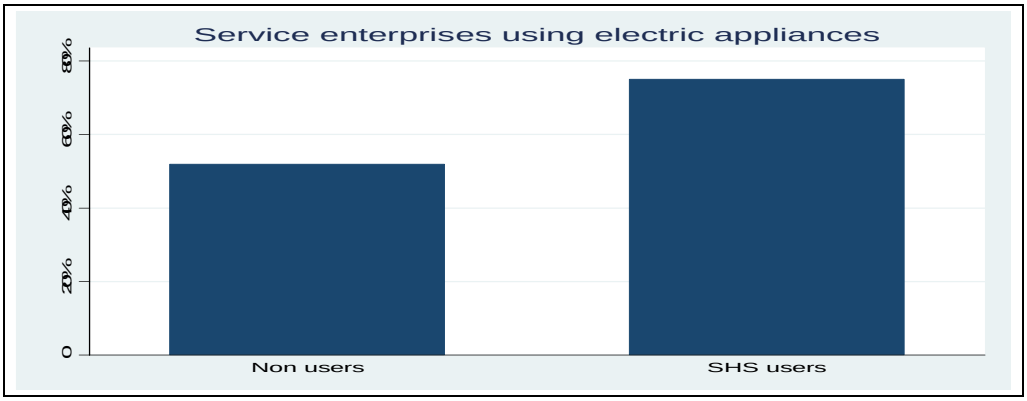


3.3.5 Use of Electrical Appliances

As it will be further demonstrated in the investment section the use of electrical appliances is higher in microenterprises using solar systems than in microenterprises without SHS. Although not surprising, the findings underscore the fact that SHSs increase the productive use of electric appliances in addition to electric light and notably of electric hair cutters, cell phones, radios and televisions. While about 50%

of the non users use electrical appliances, this figure seems to increase due to solar electricity to nearly 80% (see table).

Figure 7: Service enterprises using electric appliances



3.3.6 Use of Electricity

The majority of microenterprises interviewed in the selected sub counties of the non-access region do not use any form of electricity in their businesses but rather use kerosene lamps, battery powered torches for lighting, or close down business at sunset. This is because their village is not electrified and they have neither installed a SHS nor a generator. Most remote rural locations in Uganda are not electrified. Solar energy is hence an increasingly interesting electricity source of which 7% of service enterprises make use after 2 years of local availability. The other alternative electricity sources, apart from grid electricity, are generators and are used by very few enterprises to power heavy machinery such as milling machines and welding equipment. Further, some micro enterprises in the non access as well as in the access region that do not own SHS use automotive batteries mainly for lighting and radio (about the same number as SHS users). It can thus be concluded that SHSs are popular in remote rural locations without grid electricity, mainly for lighting since they provide a clean and in the long run cheaper source of energy. However, more affordable schemes need to be made available to increase access to the less wealthy class of microenterprises and technical performance needs to be increased to further bring down costs for maintenance and notably blown out bulbs.

3.3.7 Use of SHS

Concerning the investment in solar systems, on average the total initial investment cost was about UGX 1 million with a range of systems that were purchased costing between UGX 200,000 and UGX 4,000,000. Asking the entrepreneurs how much they would pay for the system today, to get an idea about their satisfaction, yielded the response that on average, they were willing to pay much less (about UGX 700,000. Some entrepreneurs would not even purchase one again. On the one hand this finding might be explained through the non satisfaction of the entrepreneurs with the SHS but on the other hand it might be that entrepreneurs wanted to express that the investment was important and that, if possible, they would pay less today. Further, entrepreneurs are aware of falling prices and hence expressed that they will not pay more than the actual market price. This argument is confirmed by the interesting fact that the non users who are interested in purchasing a SHS are willing to pay the same amount as quoted by the users (about UGX 700,000). As 83% of the non users showed interest in purchasing a SHS and as 86% of the SHS users are said to be generally satisfied with their system, it can thus be concluded that investing in a SHS is a popular electrification option for users as well as for non users in remote rural locations without grid electricity.

3.3.8 Technical Performance of SHS

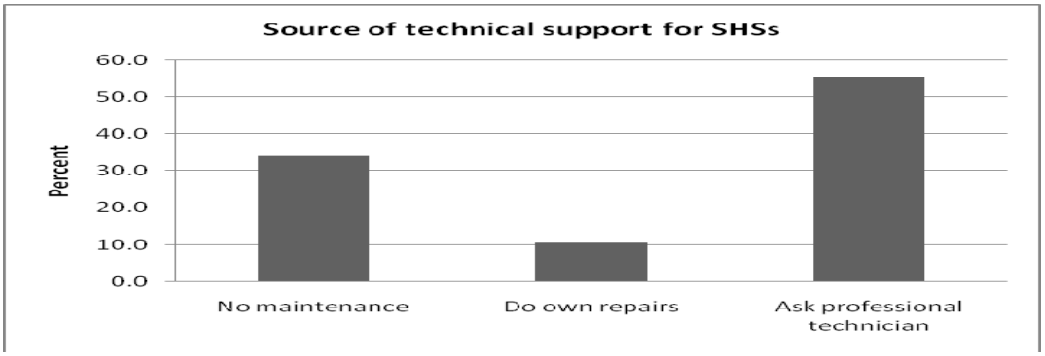
In order to assess the technical performance of solar systems in microenterprises, a definition is needed of what a solar system is and what it comprises. Here a broad definition will be applied that includes the solar panel, the charge controller, the battery, the inverter, if existent, the wiring including switches and the electric lighting devices, and in some cases, an outlet for phone charging. Although it might not be intuitive for western consumers to include the electric bulbs in the definition of a solar system, rural African consumers on the one hand do not have the possibility to quickly purchase a new bulb. On the other hand, the costs for bulbs are considerable (UGX 15.000-20.000) which they might not be able to bear instantly. As light is the main use of solar energy, if not working, the system is useless and sometimes remains useless until a new bulb is purchased.

All the three PREEEP supported companies sold SHSs to the microenterprises as complete sets, hence, comprising of a solar panel, charge controller, a sealed battery and electric bulbs and in some cases an inverter. All system installations were done by experienced technicians appointed by the solar companies, who also provided free after sales services during a warranty period of one year for system related malfunctions. Maintenance is done at no cost to the SHS owner for the first year, with the only charge being transport to and from the SHS owner's premises and the cost of blown out bulbs in most cases – which is the reason for the high monthly maintenance costs. In some cases, mainly in Rakai, solar companies admitted having received sub standard bulbs initially and they addressed this with their service provider subsequently.

Half of the microenterprises with SHSs purchased from the three companies expressed having encountered technical problems with the systems, with the main three problems being faulty bulbs; the systems not lighting at all or for less hours; and the batteries not charging fully or having a low capacity. Some of these faults were attributed to poor quality equipment, notably bulbs and batteries. It seems that some of the batteries are not deep cycle and start degrading after a few months. Other faults were due to improper usage of the systems, whereby some clients overload the systems with more lights or phones than initially intended, hence causing the system to fail.

The findings show that a bigger proportion of the SHS users utilize the services of experienced technicians to carry out repairs in the eventuality of system faults. On average the maintenance costs to users are about UGX 10,000 per technician visit. This cost is considered high by some users who try to carry out their own repairs, often causing further damage to the system. This category of users is however small, represented by 10% (see graph).

Figure 8: Source of technical support for SHSs



3.3.9 Improvements to SHSs

Whereas the majority of technical faults can be attributed to improper usage of the systems by the users, the nature of faults experienced point to the need for SHS improvements to focus on the quality and durability of system components including long lasting bulbs and stronger batteries. As illustrated in the graph below, the majority of users have the impression that the batteries supplied are not strong enough to store power. This coupled with increased sensitization of the users on the limits of the system would increase user satisfaction and support the market for solar products.

Table 5: Improvements that can be made to the SHS

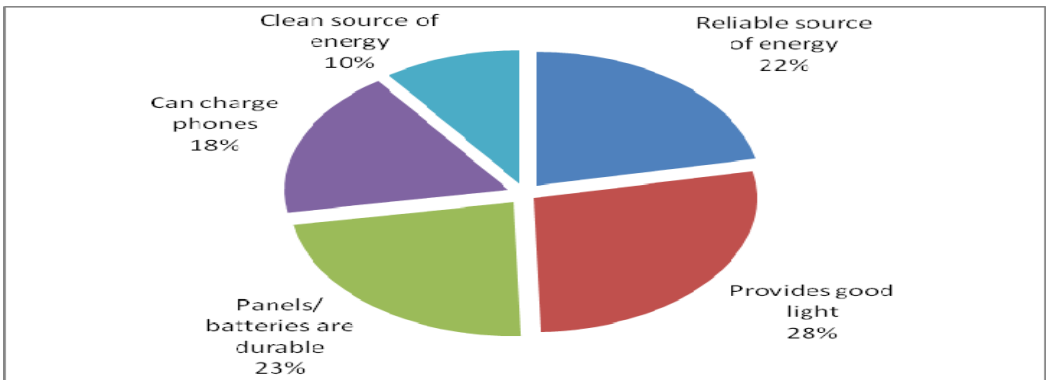
		Frequency	Percent
	Strengthen the battery capacity	20	62.5
	Increase the panel sizes	5	15.6
	Reduce the price	1	3.1
	Improve durability of system components	5	15.6
	Nothing	1	3.1
Total		32	100

3.3.10 Strengths and Weaknesses of SHS

As already highlighted, the main use of solar products in non electrified rural areas is lighting. In line with this finding, the main strengths attributed to the SHS were the

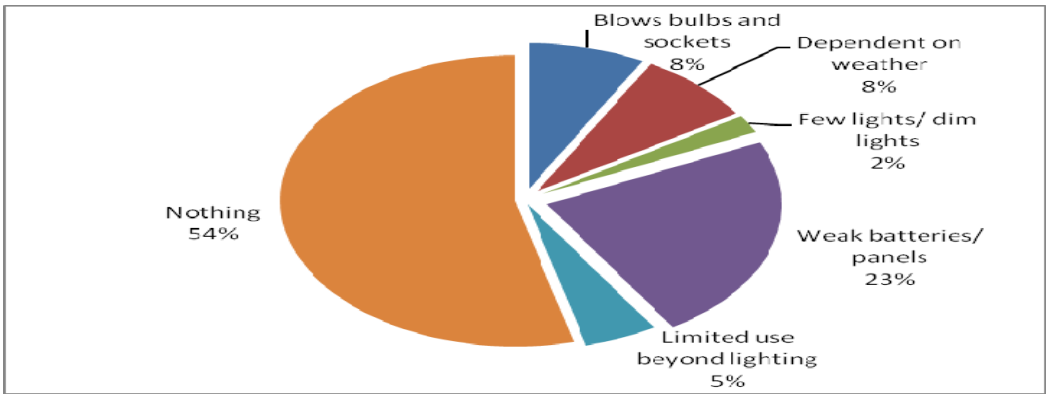
fact that it provides a good and cheaper source of light; is clean, reliable and can power electric appliances such as mobile phones and radios (see chart).

Figure 9: Strengths of the SHS



The weaknesses of the SHS on the other hand stem from its dependence on weather conditions for its effective functionality. Whereas the majority of microenterprise SHS users (54%) could not cite any weaknesses of the system, 23% reported that the batteries and panels were weak and that the batteries were incapable of storing adequate power. The frequency of solar power outages was however found to be less than three times in a single month, with only 11% experiencing outages beyond three times in a month. It could thus be inferred that the outages were more a result of bad weather conditions rather than any other technical faults. Other weaknesses relate to the limited capacities of the installed systems (which is not a technical default) and weak batteries/ panels (weaker than they should be) as illustrated in the chart below.

Figure 10: Weaknesses of the SHS



The above weaknesses notwithstanding, the majority of SHS users (86%) would recommend a SHS to other small business owners. The main benefits mentioned are that it is a reliable energy source, can boost business profits through phone charging and quality light, and reduces energy costs in the long run. Also among the SHS users, over 60% are interested in upgrading their systems with additional panels and batteries mainly to be able to increase power output for more lights and to charge more phones.

Table 6: SHS Users interested in purchasing additional panels

		Frequency	Percent	Cumulative Percent
	Yes	29	65.9	65.9
	No	15	34.0	100.0
Total		44	100.0	

Overall, the SHSs supplied by the supported solar companies have been rated as reliable and clean sources of energy by 86% of the SHS owners, with many of them expecting the systems to operate well for many years in the future. These findings help to promote the reputation of these solar companies amongst prospective buyers within the program access regions.

Table 7: Reliability rating of SHS by microenterprises

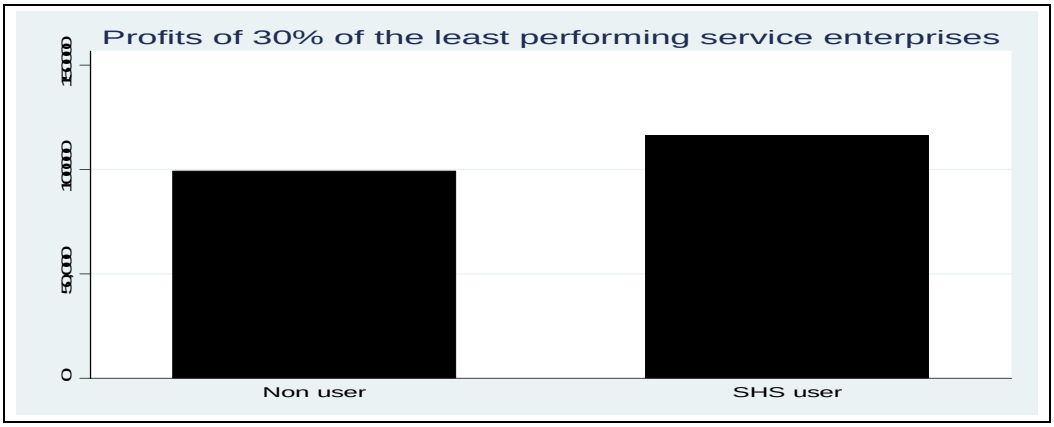
Rating		Frequency	Percent
	Very reliable	17	48.6
	Reliable	13	37.1
	Not very reliable	4	11.4
	Not reliable	1	2.9
	Total	35	100.0

3.4 Profits

A comparison of profits of SHS users with the non users shows that SHS users in the access region have significantly higher profits than non users. As already mentioned, to reduce the selection bias matching was done to only compare similar and potential

users in the non access region. Considering that the selection bias in this section has been further reduced through matching of only considering 30% of the least performing service enterprises, the remaining difference in profits may thus be attributed to the use of SHSs. The explanation is that notably enterprises that use solar light work for longer hours and are able to attract more customers due to brighter electric light and hence make higher profits as illustrated in the graph below.

Figure 11: Reported profits of 30% of the least performing microenterprises with and without SHS



The hours of operation are prolonged by one hour per day among the SHS users. In a month with at least 24 working days and 12 hours of work per day, it would mean that solar light might lead to two additional days of income per month (see table 12). Calculating the average profit of the users of the sub sample of UGX 116,250; two days account for an additional profit of roughly UGX 10,000 per month which is half the monthly wage of one employee and might partly explain the UGX 16,000 higher profits of the users. Profits increase due to the attracted new clients.

With the lack of customers and local satisfied markets being reported as the main hindrances to increased sales, these findings thus indicate a skewed distribution of the existing demand in favor of microenterprises with SHS. Accordingly, non-SHS users may lose customers, while SHS users are making gains. While SHS users attract around 18 customers per day, non users in the non access region attract around 16. Interestingly, non users in the access region only attract 12 customers per day whereas in the same trading centers SHS users have about 18 customers. Thus, it can be

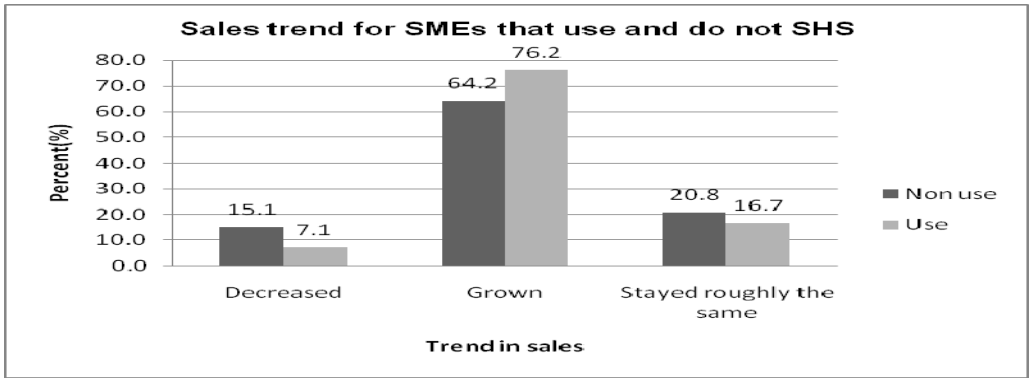
concluded that the lost customers of the non users are attracted by the users (see table). In consequence there is no effect on the local economy as a whole as the demand is only shifted from the SHS users to the non users.

Table 8: Hours of operation and customers per day by microenterprises using and not using SHS

	Operation hours per day	Customers per day
Non users in the non access region	12.3	16
SHS users	13.3	18
Non users in the access region	12.4	12

An analysis of the trend of sales development also revealed that although the majority of both categories of microenterprises (users and non-users of SHS) expressed a growing trend in sales, the growth was more pronounced among microenterprises using solar than among those that do not use SHS as illustrated in the graph below.

Figure 12: Sales trend for microenterprises that use and do not use SHS



Accordingly 76 % of the microenterprises with solar systems reported a growth in sales over the past year, followed by 17% with static growth and only 7% reporting a decline in sales. In contrast, there were more microenterprises without solar systems that reported static growth (21%) and a decline in sales (15%) which is twice as high as in the case of microenterprises with solar. The main reason, explaining the reported growth in sales among solar system users, was the increase in customers/demand for products and services as a result of longer working hours and the availability of light.

On the other hand, static sales growth was attributed to seasonal effects, whereby businesses experience peak seasons for sales during holiday seasons and low sales in other months. Declining sales- especially among the SHS non users- as already mentioned in previous sections, are due to stiff competition amongst microenterprises engaged in the same products/services and a general lack of demand. This underscores the hypothesis that the demand is only shifted from non users to SHS users which in consequence leads to a reorganization of the market structure in favour of SHS users with no effect on the growth of the local economy.

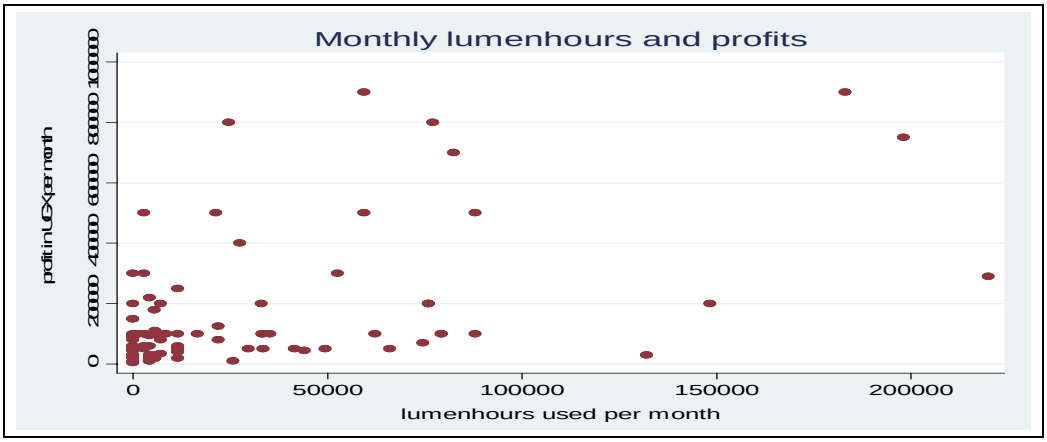
3.4.1 Profits in Relation to Lumen Hours

While some energy experts presume that the use of more and better light has a positive effect on a company's profits, results from the interviewed enterprises in rural Uganda do not entirely support this point of view. Analyzing the correlation between profits and the level of light usage, it comes as a surprise that not even a trend can be found (see graph). Although - as the graph is illustrating - a trend cannot be observed, it is a fact that SHS using enterprises extend their work with electric light at night and make higher profits. Accordingly, they consume more lumen hours. Nevertheless, there are also enterprises having no light or using hurricane lamps with weak consumption of lumen hours that perform as well as those using electric light. Furthermore, if there is correlation, the direction of causality remains unclear.

High profits may also influence the way that electric lights are used. In any case most entrepreneurs are not aware of the rating of electric lamps. A 20 Watt fluorescent tube has five times the lumen output of an energy saver of 7 Watt whereas asking the entrepreneur and the clients what kind of difference it makes the answer is "none". Current research confirms that it is not the *consumed energy amount* but the *service* that is provided by the energy which makes the difference. Accordingly it is the service provided (electric light, whatever the intensity and amount of light output) which is responsible for an impact on sales and profits. Hence while the service provided by energy savers is perceived as the same as the service provided by a 20 Watt fluorescent tube, the lumen output of the latter is significantly higher. Nevertheless, an energy saver is believed to illuminate as well as a fluorescent tube

(even if it is slightly dimmer). Thus clients are attracted by electric light in general, hence, making no difference between 7 or 20 Watt lamps. As a conclusion other variables such as the simple existence of electric light seem to influence the firm performance more than the quantity of light measured in lumen hours.

Figure 13: Monthly lumen hours and profits



3.5 Turnover

In line with the higher profits of SHS users, their turnover is also significantly higher. Considering that the sample only includes service enterprises and mainly shops, it can be concluded that sales grow due to longer hours of operation and an increased demand. Thus, notably the expenditures for primary goods and merchandise are expected to be higher too as shown in the next section.

Interestingly, comparing the turnover of non users in the access region to the turnover of enterprises in the non access region it turns out that the turnover is higher in the non access region. This might further confirm the finding that in the access region non users lose customers and market share to SHS using enterprises (see table).

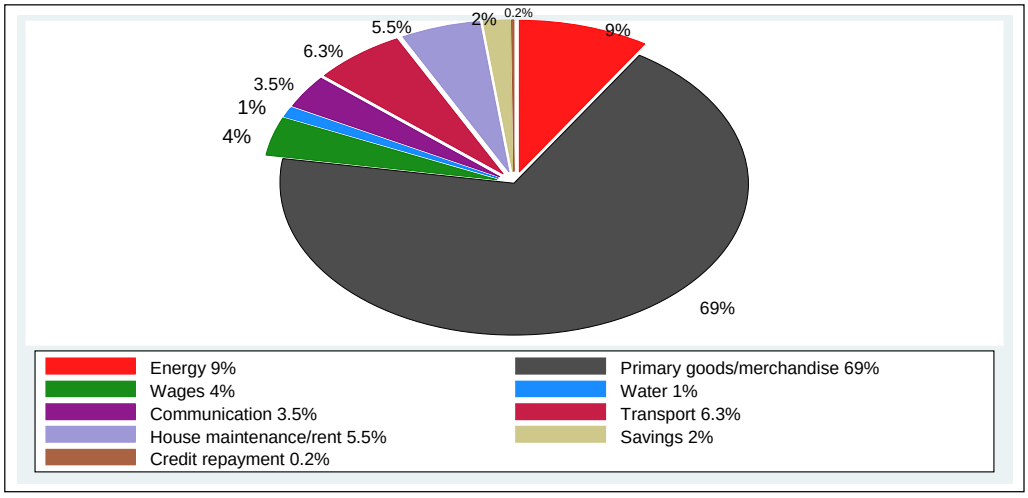
Table 9: Turnover of microenterprises on a matched basis

Use	Access		
	Non access	Access	Total
Non users (UGX)	215,392	182,358	203,157
Frequency	17	10	27
SHS users (UGX)	944,167	549,688	593,519
Frequency	2	16	18

3.6 Expenditures

The analysis of the composition of monthly expenditures confirms the picture of increased expenses on merchandise by enterprises using solar systems. Interestingly, the ratio of expenditures for primary goods and merchandise accounts for over 80% of total monthly expenditures for SHS users compared to 70% for non-users.

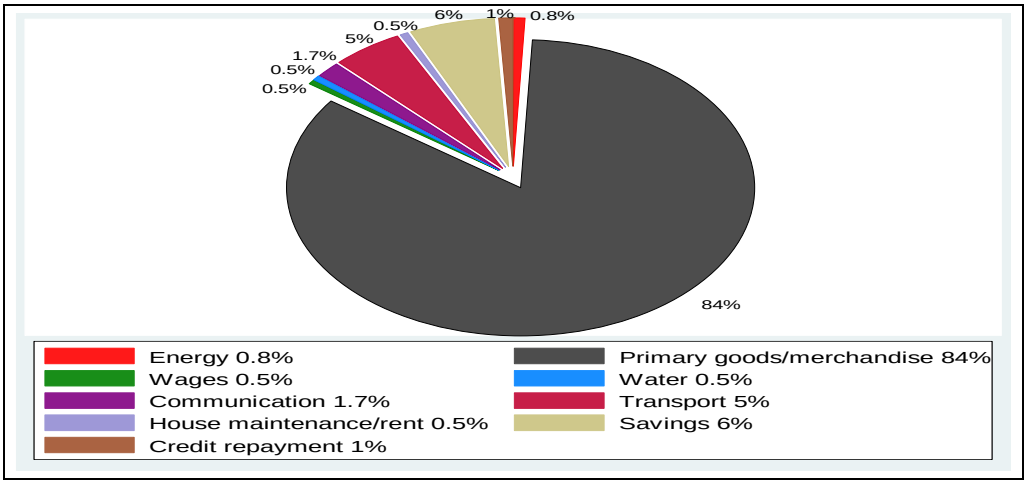
Figure 14: Repartition of expenditures of service businesses among enterprises without SHS



Concerning the energy expenditures, although they account for about 10% of the total expenditures in the case of non-users but for only 1% of the total expenditures for users, this is due to the much higher total expenditures and not due to the reduced energy costs as previously demonstrated in section 3.3.1. Further, it is worth noting that SHS owners are more prone to utilizing financing options as saving and credit options are increasingly used. Credit repayment (for both solar and business capital),

together with savings, account for about 7% of SHS users' expenditures and only for about 2% of the non-users. Promotion campaigns and assistance in financing SHSs may have contributed to this.

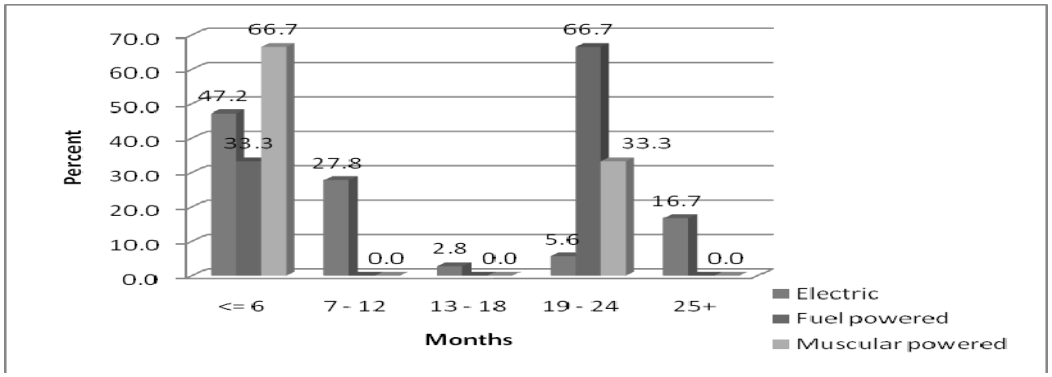
Figure 15: Repartition of expenditure of service businesses – SHS users



3.7 Investment

An analysis was made of the types of assets used by microenterprises alongside the period of use of these assets to ascertain whether access to SHS influenced the investment decision. The chart below shows the trend in the types of assets acquired and used by microenterprises that use solar systems and those that do not use solar systems in the PREEEP access regions.

Figure 16: Appliances owned by microenterprises that use SHS by period of use



There is an increasing trend in the purchase and use of electric powered appliances by microenterprises with SHS over the last 18 months, with the majority (47%) of electric assets having been acquired within the last six months compared to 28% and 3% respectively in the last 12 and 18 months. The types of electric powered assets acquired mainly include cellular phones and salon equipment such as hair clippers as highlighted in previous sections. One can interpret the higher investment rate as an indicator of economic well being of the enterprises which invested in solar systems. Further, it demonstrates the fact that entrepreneurs using solar systems seem to have confidence in their economic development prospects.

3.8 Labor Productivity

To evaluate the operating efficiency of enterprises with and without SHS, labor productivity can be used as an appropriate indicator. Given that profits are higher among solar system users, but which use only slightly more labor than the non users, it is obvious that labor productivity is higher among SHS users: By increasing the capital through an investment in a SHS, higher profits and thus higher labor productivity seem to be realized.

However, since local markets are often quasi saturated and demand restricted, further capital and labor input in businesses using SHS does not seem to lead to total higher sales rates in the region but to diminishing capital and labor input among businesses without SHS. The result is a redistribution of profits towards bigger enterprises. In consequence – notably through economies of scale[9] – higher labor productivity is achieved in SHS using businesses. An hour of labor in SHS using enterprises generates profits of UGX 414 per hour (0.2 USD) as compared to only UGX 152 (0.07 USD) in the case of the non-users. On average, an hour of labor in OECD countries generates 38 USD, which further impressively highlights the absolute poverty in rural Uganda. These observations are consistent with economic theory which predicts that an increased capital input (investment in SHS) leads to an increase in labor productivity.

[9] Economies of scale are cost advantages that a business obtains due to expansion.

Table 10: Labour productivity of microenterprises using/ with access to SHS and non-users

	Accessibility to local solar products	
Use	Non access	Access
Total hours of work per month - Non users	379	458
Frequency	17	10
Labor productivity	UGX 152 per hour	UGX 156 per hour
Total hours of work per month - SHS users	506[10]	556
Frequency	2	16
Labor productivity	UGX 143 per hour	UGX 414 per hour

Interestingly, employees in businesses with SHS do not seem to benefit from the company's higher profits and higher productivity. An employee earns between UGX 20,000 and UGX 30,000 per month irrespective of whether the business uses a solar system or not. Accordingly, one hour of work is paid between UGX 70 and UGX 110. There seems to be a socially accepted and applied tariff within the service sector, independent of whether the business realizes high or low profits, uses solar systems or not.

The findings show that as a result of the longer hours of operation, the number of employees in businesses that use SHSs is slightly higher. On average, such enterprises employ about two full time employees whereas businesses without solar systems employ on average one full time and one half time employee. Although the difference seems to be marginal at first glance, the impact can be important if one considers that with every two SHS installed, one job is created. These figures however have to be interpreted with caution, as it might appear that with every two SHS installed, one micro business is ruined so that the net impact on the local economy might be zero.

[10] Users in the non access region purchased a SHS either from outside the region (in the capital Kampala) or got it through a former donor project.

Table 11: Average number of employees in microenterprises that use/do not use SHS

	Accessibility to local solar products		
Use	Non access	Access	Total
Non users	1.4	1.6	1.4
Frequency	17	10	27
SHS users	2	1.9	1.9
Frequency	2	16	18
Total	1.4	1.8	1.6
Frequency	19	26	45

3.9 Capital Productivity

Concerning the capital productivity, the picture is similar to the one for labor productivity. Due to the relatively higher profits and moderately higher capital endowment of SHS users, which might be a consequence of increased investments in the course of the use of SHSs as demonstrated in the investment section, the capital productivity calculated as a stock figure is higher among the users in the access area. The capital productivity of non-users in the non-access area is 0.02 in comparison to 0.04 of the users, which means that one UGX in value of capital stock generates 0.02/0.04 UGX of profits per month. The higher capital productivity once again seems to be realized due to economies of scale. As a conclusion, it seems to be profitable to invest in capital which enables to expand the business in the way that economies of scale are realized. SHSs and related electrical appliances that use electricity in a productive way and notably electric light seem to be such an investment.

Table 3.9: Capital endowment of enterprises using and not using SHS

	Accessibility to local solar products		
Use	Non access	Access	Total
Non users (UGX)	2,799,875	1,103,882	2,108,915
Frequency	17	10	27
SHS users (UGX)	2,600,000	3,802,583	3,630,786
Frequency	2	12	14

3.10 Finance

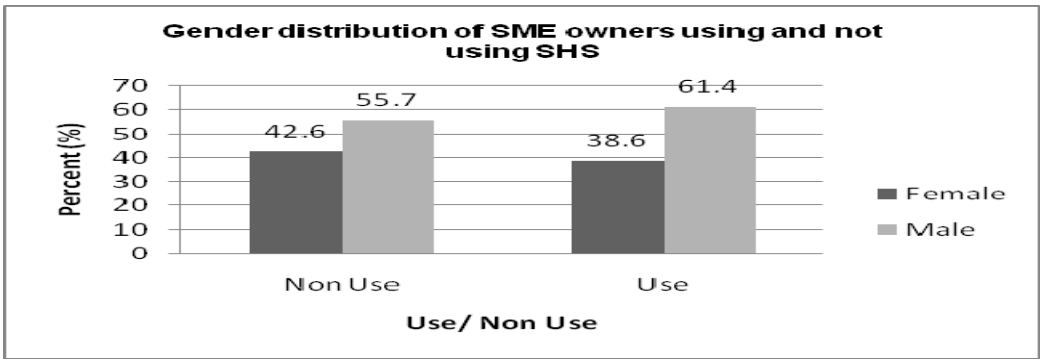
In line with the finding that SHS users seem to make more use of financing options than non users, 50% of them hold savings accounts whereas this is the case for only 10% of the non users. Further, about 40% of the users have ever applied for a loan at least once, compared to only 15% of the non-users. But since 30% of the SHS users utilized a financing option to purchase the solar system, and given that it is a requirement for one to have an active savings account (not for the SEU installations) prior to accessing a loan, it becomes obvious that investment in solar might be the reason why SHS users make more use of financing options. The loans taken are mainly from MFIs which do not require the borrowers to mortgage large securities, but rather rely on chattel items and guarantees from fellow members, which makes them even more accessible. However, a side benefit of the investment in solar seems to be financial literacy, higher savings rates and an increase in the use of financial instruments to run the business.

Out of the SHS users that had utilized financing options, 17% reported to have experienced difficulties in repaying the monthly installments. This is largely due to many family related expenses that depleted the business of capital necessary to generate income to meet the business expenses. Generally however, a bigger percentage of the SHS users were able to meet their monthly loan repayments on time.

3.11 Gender

There are more male SME owners than female owners. This is largely due to the enterprises being a means of sustenance for households and are therefore run and managed by household heads (men). The figure below shows the breakdown of microenterprises that use and do not use SHS by gender.

Figure 17: Gender distribution of SME owners using and not using SHS



The figure shows more male microenterprise owners than females represented by 56% and 61% respectively. The disproportion between male and female microenterprise owners using SHS (23%) is almost twice the disproportion between male and female owners of business without SHS. This indicates that male microenterprise owners are likely to purchase SHS systems. One might conclude that in addition to the disproportionate effects of market based development approaches which favor the wealthier social stratum, male owned enterprises seem also to benefit more than female owned ones.

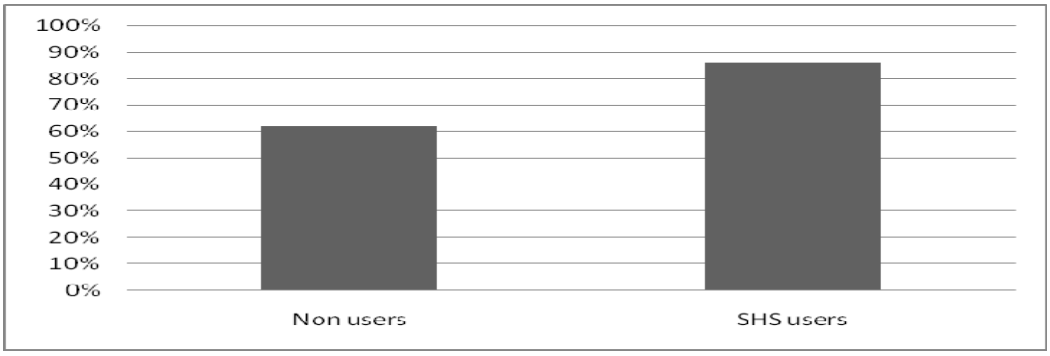
The main kinds of enterprises run by women using SHS are shops (44%), bars (18%) and clinics (17%). Whereas 42% of the male SHS owners expressed the greatest benefit of the system to their business to be phone charging, the biggest proportion of females with SHS (50%) placed more importance on lighting. This could further indicate that phone charging - an emerging business due to the availability of SHS is undertaken more by men than women.

3.12 Telecommunication/ Cell Phone

As highlighted in previous sections, the use of cell phones among microenterprises for business purposes intensifies with the availability of electricity sources for phone charging. As the mobile network is almost available in the whole country it can be excluded to be a reason for the higher amount of cell phones in SHS using businesses which in consequence might be attributed to the charging possibility. Out of the

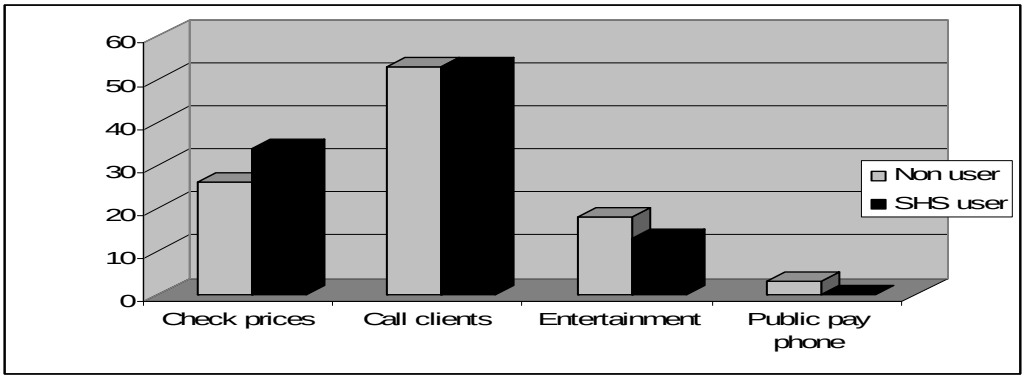
microenterprises that invested in a SHS 86% use mobile phones for their work whereas only 62% of the non users of SHS do.

Figure 18: Use of cell phones for work by enterprises



Asking the entrepreneurs what they use the cell phone for, half of them mention that they call clients irrespective of whether they use a SHS or not. Only a few of the entrepreneurs use the cell phone as a public pay phone making direct profits from its use. Further, about one third use the cell phone for checking market prices (see chart).

Figure 19: Reasons for use of cell phones for work



Given that telecommunication enables the cost effective checking of market prices and making business arrangements like orders, an increased use of business cell phones might lead to further efficiency gains, market opportunities; investments and in the end to higher profit, business expansion and development in general.

The findings also reveal that there is more cell phone use for work among males than among females with the majority of calls being made to check prices, place orders and check on clients.

Table 12: Use of cell phones for work by gender

Use		Male	Female	Total
	Yes	24	14	38
	Percent	92%	78%	86%
	No	2	4	6
	Percent	8%	22%	14%
		26	18	44
Total		100%	100%	100%

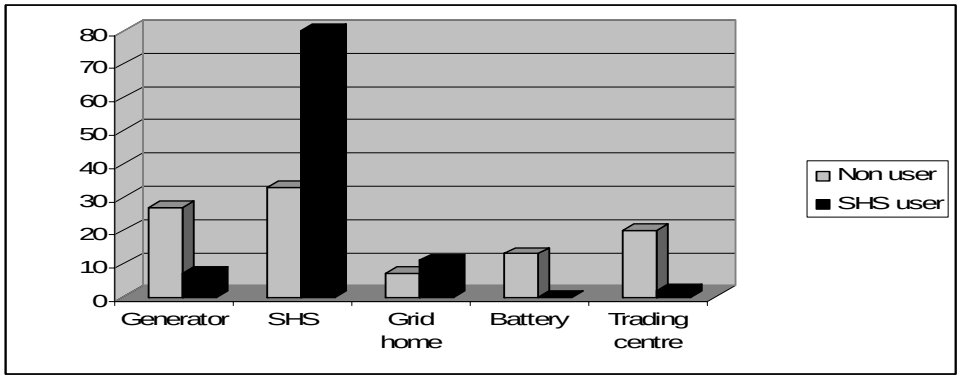
On the other hand, females who are largely engaged in service businesses use their phones mainly to check on their clients as illustrated in the table that follows.

Table 13: Main use of cell phone by gender

Main use of cell phone		Male	Female	Total
	Check prices/ place orders (N)	8	3	11
	Percent	40%	25%	34%
	Call clients (N)	9	8	17
	Percent	45%	67%	53%
	Entertainment	3	1	4
		15%	8%	13%
Total		20	12	32

In the villages that have access to solar systems, the majority of cell phone owners (about 80%) charge their phones using solar systems, a possible indication that access to SHS enables telecommunication in non electrified areas. It further enhances the finding that phone charging businesses emerge if SHSs are available in an area (see graph).

Figure 20: Power sources used to charge cell phones by microenterprises



3.13 Market Access

Contrasting market access of enterprises with and without solar systems, no difference can be found (see table below). Nearly none of the rural enterprises sell products regionally or nationwide. But as the main productive use of solar energy is electric light it comes as no surprise that also enterprises using solar systems do not access markets/ clients beyond the local ones. While the use of electric light does not seem to make any difference there is duplication in the products/ services offered. Often there is limited or no innovation to upgrade products or services which would enable the opening up of new markets. This is the reason why in previous sections it was concluded that the demand might only be shifted from non users to SHS users and not increased in general. In consequence, it was argued that smaller businesses might need to shut down due to customers that switch to businesses using solar systems.

In contrast to the enterprises that already existed before the marketing of local solar systems started, enterprises that were established as a consequence of the availability of SHS in the region expressed a slight difference in their customers/ market. Since phone charging is a highly requested new service in non electrified rural areas for which the market is not yet fully served, these newly created enterprises seem to also attract clients from outside the local market. This is due to the fact that for the new services - like for new hair cuts or phone charging – there is a high demand not only in the village that gained access to local solar energy but also in the non-electrified surroundings. Although it is only an anecdotal observation which would have to be proven through further research, there is some indication that solar energy enables

enterprises to offer new services which in consequence opens up new markets. As rural entrepreneurs quote the lack of demand to be the main hindrance to development no access to external markets combined with a weak/satisfied local demand are found to be the main contributors to the vicious circle of underdevelopment of rural microenterprises. Technical progress and diversification through electric appliances that open up further markets might contribute to a way out and might even be a major development strategy for rural electrification projects. Projects may foster the use of solar energy and appliances that enable entrepreneurs to offer new services, hence, diversifying the economy and gaining access to markets which enterprises without solar systems cannot access.

Table 14: SME access to local, regional or national markets/ clients

	Market/ client		
Use	Local	Regional or national	Total
Non users (Freq)	26	1	27
Percent	96%	4%	100%
SHS users (Freq)	17	1	18
Frequency	94%	6%	100%

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

From the analysis of the findings, the following conclusions have been drawn:

- The investment in a SHS is a question of the economic sector and the performance of the enterprises. Notably wealthier ones and specifically service enterprises (shops, bars and hair salons) invest in solar systems whereas financially weak enterprises and manufacturers (tailors, mechanics and carpenters) refrain from the investment. The reasons are high investment costs of SHS, its limited capacity to power machines and the restricted value added of electric light for manufacturers.

- The main productive use of SHS among microenterprises is lighting. Mainly for shops, bars and clinics. Additional productive uses are limited to “Solar Hair Systems” for electric hair shaving and “Solar Phone Systems” for phone charging businesses which emerges as a consequence of the availability of solar systems.

- As a consequence of the main use of SHS for electric light, hours of operation are prolonged and the better lit businesses attract more clients, consequently resulting into higher sales, turnover and profits.

- As local markets for existing products and services are saturated and demand is restricted, the increased use of solar systems by some microenterprises could lead to a loss of business for financially weak micro businesses that do not use SHSs. The enterprises without SHS could be out-competed by larger, more financially solid enterprises that are well lit, longer opened, attract more clients and sell cleaner and more hygienic products.

- In the short run, solar electricity is not a cost free electricity source as 50% of the systems seem to have technical problems with the most frequent one being blown out bulbs. As a consequence of high replacement costs for the bulbs, energy

expenditures of SHS users are as high as those of non users. In the long run, well performing SHS might reduce expenditures on other forms of energy such as kerosene as their consumption of those traditional energy sources is cut by half thereby releasing more funds for re-investment or savings.

- SHS users do not automatically climb the energy ladder as they do not switch from inefficient to efficient energy sources once solar electricity is available. Due to entrenched habits, the stationary nature of a SHS as well as technical failures and low capacity, SHS users continue to use a mix of energy sources including dry cells and kerosene.

- Access to SHSs positively influences the purchase of electric appliances such as cell phones, radios and hair salon electric equipment. However, the nature of equipment purchased is restricted by the capacity of the SHSs.

- The use of SHSs by microenterprises for only lighting purposes has no direct influence on their access to regional and national markets. This is largely because electric light only enables prolonged hours of operation as opposed to the use of electric appliances that may be used to offer new products and services and in consequence might lead to new markets. As local markets for existing products are saturated, no additional demand can be generated through only prolonging hours of operation. In contrast solar phone charging businesses offering new services might open new markets as the demand is not satisfied and clients from other non-electrified villages are attracted.

- Access to SHS has spillover effects with regard to exposure to financial services including access to loans and savings facilities and, thus improving financial literacy. This is because most SHSs are purchased on a credit basis, requiring the customers to have active accounts with the institutions.

- Although solar energy is a preferred source of energy in rural non-electrified areas, its use is restricted mainly to the well-off who are able to afford the SHSs and seems to favor men more than women due to the fact that men are more responsible for investments in general than women.

4.2 Recommendations

The following recommendations could enhance SHS program results for microenterprises:

- As it was found that market based approaches to development favor notably wealthier microenterprises and men, access to SHS might lead to further disparities in the performance of other rural businesses. In order to address inequalities, promotion campaigns should focus on the one hand on less expensive one-light systems and on the other hand on financially weak enterprises and women (Solar Micro and Women Business Systems).

- Market based approaches to disseminate solar systems should be accompanied with the enhancement of financial institutions and financial products that focus on solar loans and facilitate the take up of loans for financially weak enterprises. Further solutions might be “No Security – System Take Away Loans” that would be associated with lean administrative procedures and open finance options for financially weak enterprises.

- Additional productive use possibilities of solar systems should be studied and demand analysis conducted for new solar products and services. This should notably include the use of SHSs in manufacturing and agriculture based businesses. Based on these scientific findings, Business Development Services for the productive use of SHSs (SHS-BDS) need to be developed. These SHS-BDS need to comprise investment and business assistance plans that would enable entrepreneurs to profitably invest in solar systems. These SHS-BDS are needed so as to increase the low take up rate and foster the productive use of solar PV in rural microenterprises.

- Solar companies should develop business lines that especially promote “Solar Business Systems” that power hair shaving machines, charge cell phones and are

flexible to new business ideas like fridges to sell cold drinks/ice cream and are adaptable to other innovations. New emerging markets might be tapped.

- Solar companies should take more care not only to provide technical training to their own technicians and to supply more durable installations and solar equipment but to also provide technical training to the end user together with the installation. An integral part of this end user training needs to inform about the limitations of the system and the use of the bulbs so as to bring down the high maintenance costs for blown out bulbs and to promote the popularity of solar PV among end-users.

- The systems installed by the supported solar companies should be routinely checked for quality to ensure that counterfeit/ sub standard parts are not sold to the end users. This will largely reduce the maintenance costs incurred and enhance customer satisfaction.

- PPP with solar companies should be enhanced so as to venture into new locations for new markets, given that there is an expressed need for SHSs in the un-served regions.

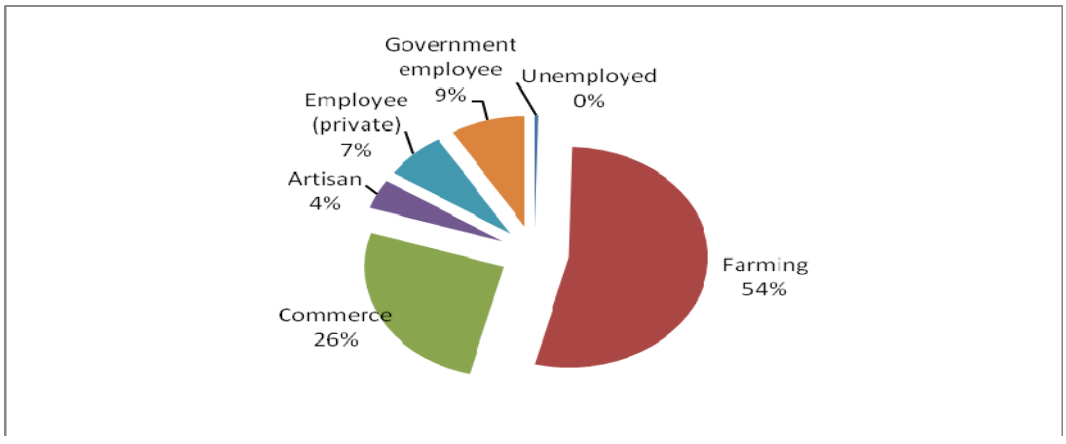
5.0 ASSESSMENT FINDINGS - HOUSEHOLDS

5.1 General Living Conditions of Rural Households

A rural household in Western Uganda typically comprises of a family residing in a homestead of at least two buildings (a main house and an adjacent kitchen), with an average of two acres of arable land. The building structures are of mud bricks and roofed with corrugated iron sheets - for the middle income households - and straw thatched roofs for the poorer households.

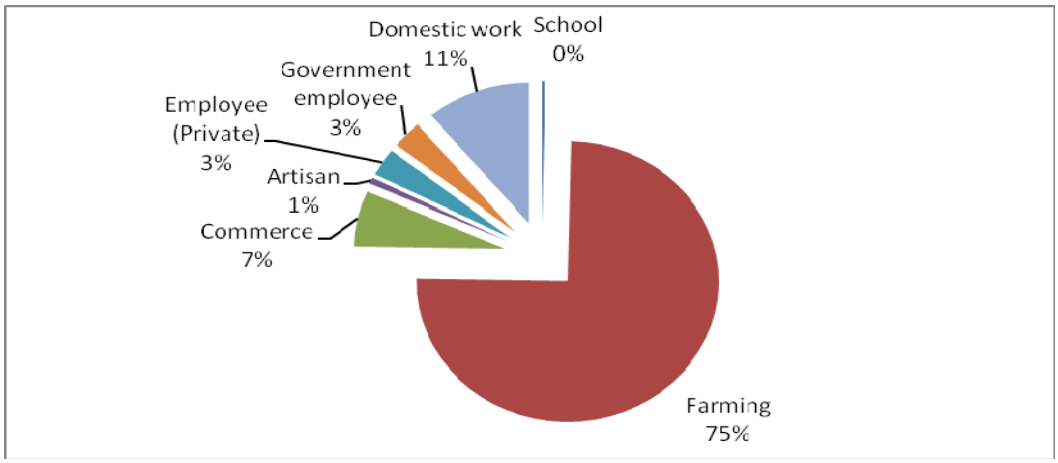
The households on average have a family size of eight persons, often with extended family relations comprising of dependants below the age of 16 and above the age of 55. Nearly 50% of the household heads in rural Uganda have attained up to secondary level of education, while the same proportion of their spouses are primary school drop outs. The main occupation of rural household heads is farming, represented by over 50% of the randomly sampled households. Other common occupations are commerce, followed by formal employment in the public and private sector respectively (see graph).

Figure 21: Regular occupation of the household head



Similar to the men, the main occupation of women is farming represented by 70%, followed by unpaid domestic work and commerce respectively as illustrated in the figure below.

Figure 22: Regular occupation of the spouse



The typical monthly income of rural households, as generated from randomly sampled households, is UGX 262, 233. Considering an average family size of eight persons, this implies a daily equivalent of UGX 1,093 per person per day ($0.5), which is below the poverty line of $1 a day.

The general difficulties that rural households have to cope with include:

- Low income to sufficiently meet household related expenses including medication, energy, food, clothing, and education;
- Inadequate shelter for the large families, who often have to share their dwellings with poultry and livestock;
- Ill health of household members coupled with limited access to health facilities. This affects household productivity and the associated costs deplete households of the already meager resources;
- Inadequate farm implements (tools, seeds and fertilizers) for use in farming, hence affecting output and the quality of yields;
- Lack of safe water for household use; and
- Limited access to established markets for agricultural products.

5.2 Socio-economic Impacts (MDG)

5.2.1 Main Difficulties of Households

The main challenge affecting rural households is poverty. Comparing the matched sample of the households that use SHSs with those that do not reveals that there is no difference between the groups, considering that the main problem households are coping with is insufficient income. About 50% mention that the income is too low to cover expenses including payment of school fees. Whereas it would be expected that the households without electricity would consider lack of electric light as one of the major difficulties, only 4% mentioned it as a main problem. But knowing that most households cope with more fundamental problems like the lack of income to meet household expenditures on basic needs, school fees, sickness and safe water, one understands that a solar system providing some hours of better light in the evening is not a major concern. Further, most of the activities that require light are performed during the daytime so that notably farmers question the utility of the high investment in SHS.

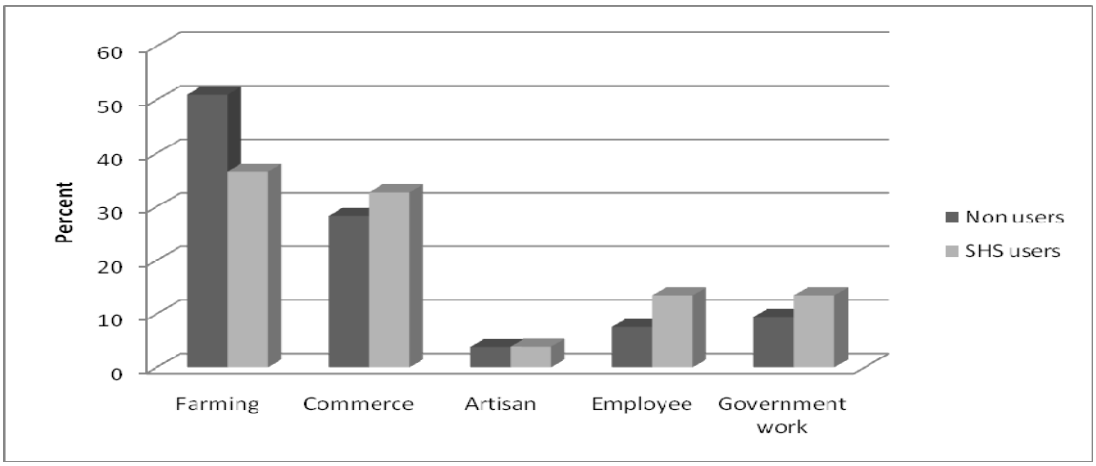
Table 15: Main difficulties of households using and not using SHS

	Non users	SHS users	Total
No problem	4%	7%	5%
Insufficient income to cover expenses	30%	26%	28%
Payment of school fees	16%	31%	24%
Sickness	14%	13%	14%
Limited land/ farm implements	9%	0%	5%
No electricity/ lighting	4%	2%	3%
Lack of food/ low yields	11%	2%	6%
Theft	0%	4%	2%
Lack of safe water	11%	7%	9%
No access to markets	2%	7%	5%
Total	100%	100%	100%

5.2.2 Occupation

The main occupation of the majority of rural household heads is agriculture irrespective of their use of solar systems. Solar systems are however more prominent among households whose regular occupation is salaried employment and commerce as opposed to agriculture. This could be explained by their higher incomes, their predisposition to opportunities associated with solar systems through their work, as well as their need for electric light to complete their work at home. This finding also underscores the fact that electric light seems to be perceived as more useful to individuals in the service industry than those engaged in agriculture.

Table 16: Regular occupation of the matched sample of household head



As already mentioned, mainly due to the employment in the formal private service sector and the government, the incomes of only the non matched SHS users are fivefold compared to the randomly sampled non users who are mainly farmers. It can thus be concluded that market based approaches to disseminate solar systems seem to favor the upper social class of wealthier and better educated households in which the household head is likely to be an employee in the government or in commerce. It should be noted that this result can be drawn after 2 years of project implementation. In the short run the benefit of the project for only the richer households is justified through the argument of building up a sustainable market and infrastructure for solar PV (for which the upper class is the entry point). However, solar PV projects need to reach the “bottom of the pyramid” and the “mass of the poor” in the long run. Not

only is it that wealthier households are not the target group of the MDGs but in the long run they might even purchase a solar system without the sustained promotion of solar companies as was the case in Kenya, where a large middle class triggered the demand for solar PV without any support.

5.2.3 Incomes

A comparison between the average monthly incomes of the matched sample of the users and non users of solar systems shows no significant difference between the two reflected by only 2%. The slight difference in incomes (UGX 297,000 and 331,667 respectively) could be attributed to the nature of occupation, with incomes in the agriculture sector being irregular and dependent on a particular season, whereas incomes of the service sector (with more SHS owners) tend to be slightly higher and more regular. However considering that the main source of income for rural households is agriculture and solar is not used in a productive way as demonstrated subsequently, it can be concluded that the use of solar systems has no influence on household incomes.

Table 17: Monthly incomes of households

	Non users	SHS users	Total
Mean Income (UGX)	297,232	331,667	314,136
Freq	56	54	110

5.2.4 Productive Household Activities

The majority of rural households do not carry out income generating activities in the evenings. Only 10% of the households (irrespective of whether solar systems are used or not) engage in productive activities in the evenings such as sorting grain and coffee, preparing soft drinks and foodstuffs for sale or teachers preparing lessons and marking assignments. This category of households works for an average of 3.5 hours each evening. Although the share of households in which productive work is undertaken does not seem to increase with the availability of electric light and may not necessarily translate into increased household income, the quality of work output is bound to improve in the case where a SHS is used due to the better quality of light.

In addition, better light allows the user not to tire out fast, as their eyesight is less strained.

5.2.5 Education

Nearly 100% of both SHS users and non users have their children attending school (see table below). As expected, this finding suggests that use of solar systems does not influence school enrolment, but rather the ability of the household to meet the school fees.. Considering that the problem of payment of schools fees was mentioned more among the SHS users than the non users, it appears that whereas the non users could be taking advantage of free education for children in Government aided schools, the SHS users – likely to pay more attention to the quality of education - are enrolling their children in private schools which are more expensive.

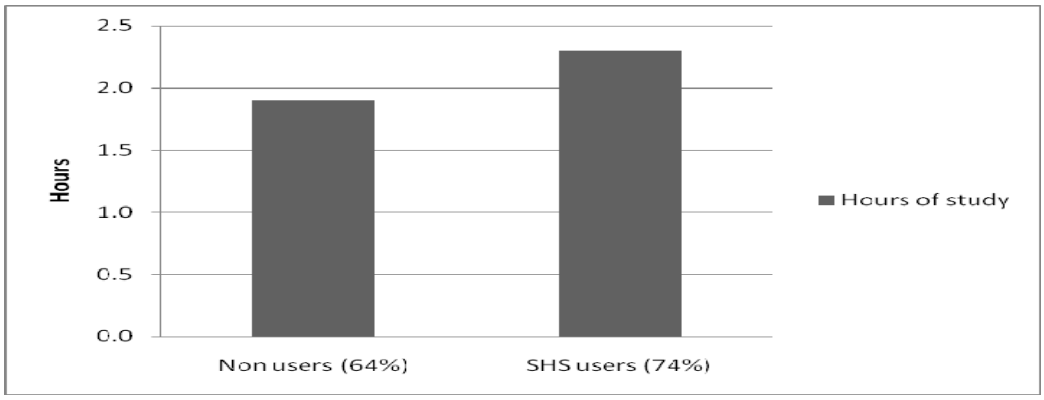
Table 18: School enrolment for children in households

			Non users	SHS Users	Total
	Children not in school	Freq	1	3	4
		Percent	2%	6%	4%
	Children in school	Freq	55	51	106
		Percent	98%	94%	96%
Total		Freq	56	54	110
		Percent	100%	100%	100%

Out of the children enrolled in school, 64 % of those from households without solar systems study in the evenings, while this is the case for 74% of the SHS users. In addition, on average, children from households with solar systems study for 2.3 hours in the evenings, while those from non using households study for only 1.9 hours. While one might attribute the increased studying of children to the higher number of employees and government workers within the SHS users, further matching of only farmer households confirms these findings that children of those using a SHS also study for half an hour longer than the non users. It can thus be concluded that use of solar electricity, although not a factor for enrolment in school, increases the number of children studying in the evening and the hours of study by an extra half hour compared to the non users, as a result of better quality light. Longer hours of study,

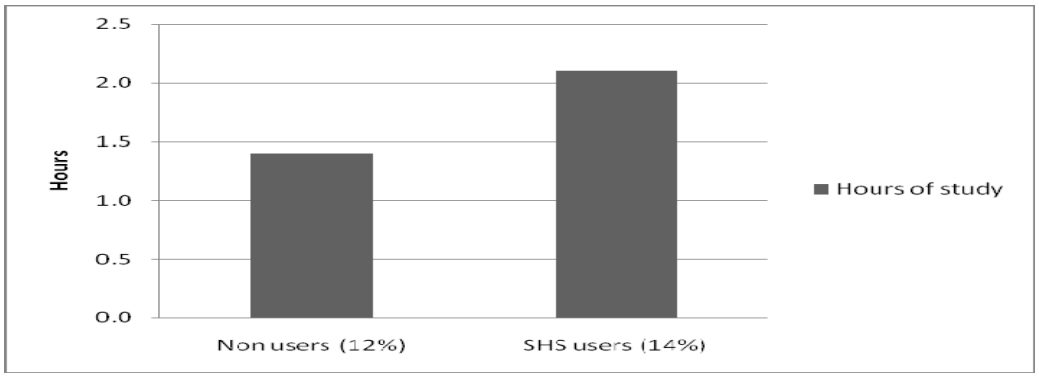
although not an aim per se, can be seen as a proxy for future impact on school performance.

Figure 23: Hours spent studying by children in households



Besides the children, roughly 13% of the household heads read/ do private study in the evening irrespective of whether solar systems are used or not (see graph). Out of the proportion who read, the SHS users on average read for close to one hour more than the non users (represented by 2.1 and 1.4 hours respectively). Further analysis of only farmer households within the matched sample confirms the results that the SHS users on average read for close to 1 hour, while the non users do not read (represented by 0.7 and 0.04 hours respectively).

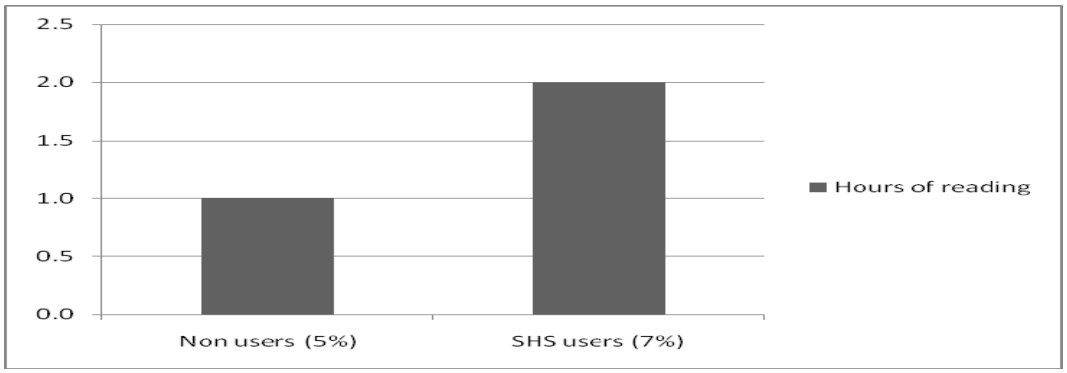
Figure 24: Hours spent reading by household heads in the evenings



A smaller proportion of women in rural households read during the evenings represented by 5% and 7% respectively (see graph below). Similar to the findings of

the children and household heads, the women from households with solar systems also read for one hour longer than those in households without solar systems (represented by 2 hours and 1 hour respectively). Hence the availability of solar light seems also to promote education among the adults.

Figure 25: Hours spent reading by women in the evenings



With regard to informative radio programs, 94% of household heads and their spouses listen to radio in the evenings irrespective of their use of solar systems. The main programs listened to include educative talk shows, public announcements and news. On average, the time spent listening to radio in the evenings is 3.2 hours and is the same irrespective of whether the household has a solar system or not. Considering that most rural households own small radios that are powered by dry cell batteries, the use of solar systems has no impact – in the short term- on the use of radios by households.

Only a few households own and watch television. Whereas 15% of the household heads watch television among the SHS users, this is the case for only 4% of the non users. These low numbers could be attributed to the inadequate capacity of the installed solar systems to power televisions, as well as the lack of electricity for the non users. Out of those watching television, the main item watched is the news which might further lead to better informed households using a SHS.

5.2.6 Gender

Occupation

As previously mentioned, the main occupation for both men and women is agriculture. Besides agriculture, more men are involved in commerce and salaried employment than women, represented by a total of 52% and 17% of the men and women respectively. Traditionally, in addition to the regular occupation, nearly 100% of the women do domestic work including cooking, washing and caring for children whereas men rarely participate in domestic work. In SHS using households, about 7% of the men (heads of households) participate in domestic work in the evenings while 14% of the non users help (on average in both types of households men who help women assist them for about 1.4 hours). This is a possible indication that the availability of solar systems creates opportunities notably for men to do other activities than domestic work such as reading, listening to radio or watching television. Hence the participation of men in domestic work seems to decrease with the availability of solar systems.

Among the women, 66% of those from households without solar systems complete domestic work in the evenings after sunset whereas this is case for 80% of the SHS users. On average the women from households with solar systems work for 2.2 hours while the non SHS users work for 1.9 hours in the evening. Further comparison of a matched sample of only farmers shows that women from households with solar systems do domestic work for close to 1.5 hours longer than the non users represented by 2.7 and 1.4 hours respectively (see table). As women irrespective of the use of solar systems start to work at the same time in the morning, it can thus be concluded that the use of solar systems leads to slightly longer hours of domestic work for women as a result of cheaper and better quality of light. Considering that the study did not investigate the net time spent by the women in doing domestic work, these findings could also indicate that the women in households with solar systems simply stretch their hours of work due to the availability of light.

Table 19: Hours of domestic work by farmers women in the evenings

	Mean (Hours)	Frequency
Non users	1.4	27
SHS users	2.7	19
Total	2.1	46

Income

The findings also reveal that women in households generally earn close to three times less than the men (UGX 123,636 compared to UGX 299,091 respectively). This disparity could be explained by the ability of men to diversify their income sources unlike the women who have to balance their hours of productive work with domestic work which is unpaid. Solar systems, as mentioned before, seem to have no impact on income of neither men nor women.

Table 20: Incomes of men and women in rural households

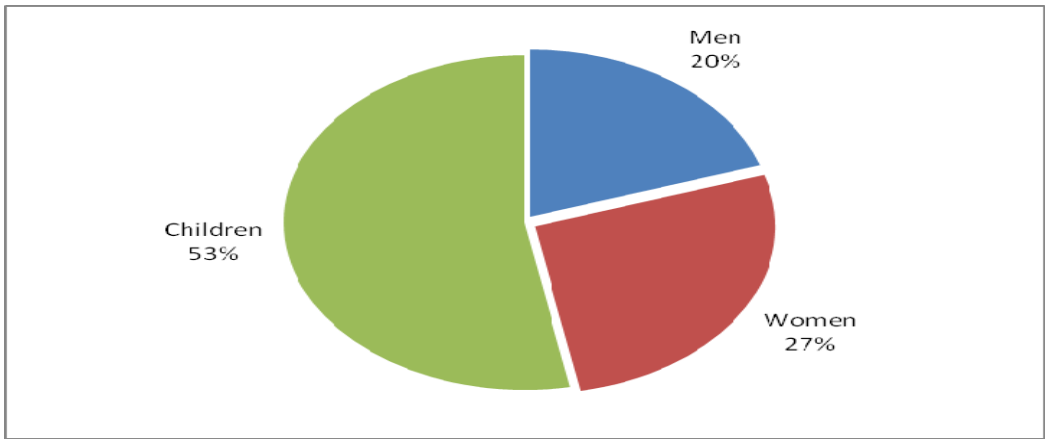
				Total
		Non users	SHS Users	
Household head income	Freq	56	54	110
	Mean (UGX)	283,929	314,815	299,091
Spouse income	Freq	56	54	110
	Mean (UGX)	117,857	129,630	123,636
Total	Freq	112	108	220

Benefits of SHS

With regard to the benefits from solar systems, the main beneficiaries in the households are said to be children (53%), who mainly use it to complete their homework and study in the evenings. Next to the children, the findings show that women are said to benefit more than the men represented by 27% and 20% respectively (see graph). Despite the plausible results, these answers should be interpreted with caution as the main interview partners were men who estimated that the women mainly benefit from the quality light which enables women to complete their household chores after sunset. Men on the other hand reported to benefit more from phone charging and, to a limited extent, light for private reading. These findings reveal that as the working conditions for women improve, the hours of work also

increase. Accordingly, the judgment as to whether electric light is a benefit or not to the women should be left for them to individually decide.

Figure 26: Main beneficiaries of SHSs in households



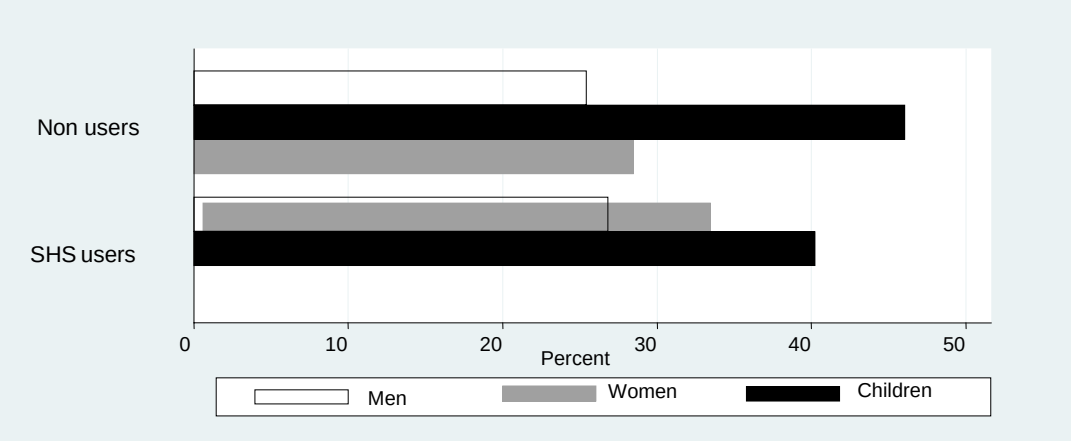
5.2.7 Health

The assessment of the impact of solar systems on household health focused on the incidence of respiratory tract infections and eye related illnesses among households that are and those that are not using solar systems. It was found that more respiratory tract infections are reported by non users than the SHS users (see graph). The most affected within the households are children- over 45% in households without SHS compared to 40% in households with SHS, followed by women and men respectively. The findings further show slightly more respiratory tract infections reported among women than men. In line with the finding from global literature, that indoor air pollution is largely a result of the inhalation of firewood and charcoal fumes as opposed to kerosene fumes, these results would be expected. A comparison of only the farmer households also reveals slightly more respiratory tract infections among the non users than the SHS users represented by 19% and 5% respectively.

The high incidence of illnesses among children from the households without solar systems could be attributed - on the one hand - to the close proximity of the children to kerosene lamps while studying in the evenings on a regular basis. On the other hand, considering that respiratory tract infections are largely airborne, the children's

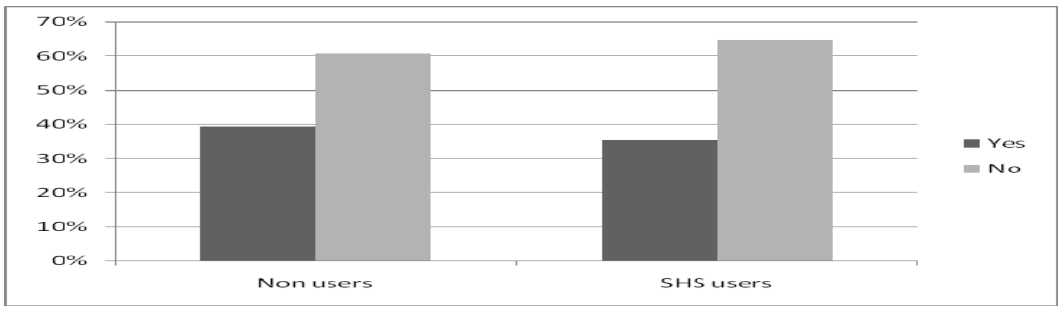
interaction with their peers at school could also explain their increased susceptibility to infections.

Figure 27: Respiratory infections among household members



Only 27% of the households (SHS users and non users) worry about the health risks associated with inhalation of kerosene fumes. The risks include difficulties in breathing, allergies and headaches from smoke and the contamination of food items by the soot from the kerosene lanterns. The findings are similar between users and non users considering that households with solar systems continue to use kerosene lanterns to light places not equipped with solar light. In regard to the occurrence of accidents from lighting devices among households, no significant difference was found between SHS users and non users. Whereas 39% of the non users had ever experienced an accident of a household member, this was the case for 35% of the SHS users (see graph). Considering that the exposure is relatively the same since both types of households use kerosene lanterns, the use of solar systems has no significant impact on the risk of accidents among households.

Figure 28: Occurrence of accidents in households from lighting devices

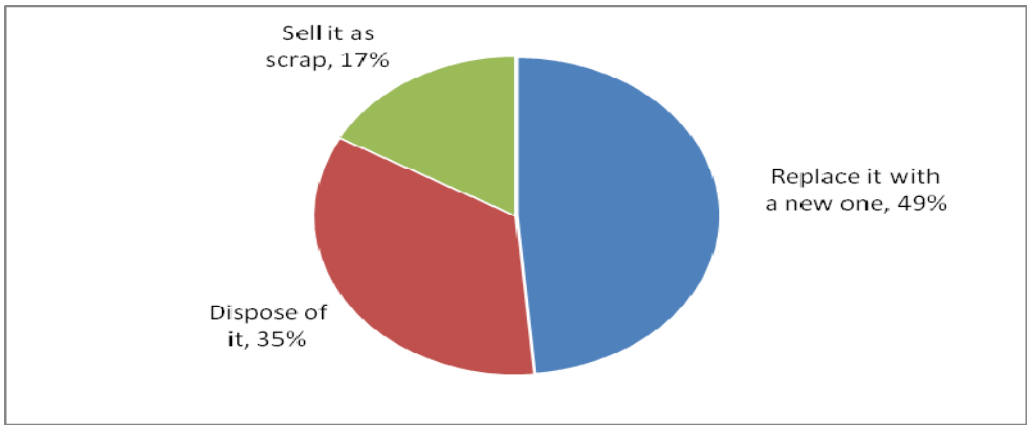


5.2.8 Environment

As the total amount of kerosene used by SHS users and the non users is non significant, the environmental impact and notably the impact on the climate through CO_2 emissions is virtually not existent for a single household. Calculating using an average consumption of 3.2 liters per month, carbon emissions from kerosene for illumination can be estimated at 8.6 kg per household which is about 100 kg a year. If households completely reduce their consumption of kerosene to zero due to their use of solar systems, it would take about 10 years to save 1 ton of CO_2 emissions, which demonstrates the fact that rural African households are low carbon emitters and not contributing to global emissions. The rest of its used energy sources mainly come from biomass which is, if form sustainable forests carbon neutral. An average US household- the most emitting in the world- emits about 12 tons of carbon per year. Looking at the project objective of 13,000 households to be electrified with solar home systems, the impact on carbon emissions if the goal is achieved and kerosene consumption totally stopped, would be 1,300 tons less carbon emissions per year. Nevertheless, this is equivalent to only the emissions of 100 US households.

As households have used their system for not longer than 2 years, most households have not contemplated the environmental impact of disposal of the SHS batteries which is expected to be after 3-5 years. Out of the responses generated from households, nearly half reported that they would return the batteries to the solar companies for proper disposal and obtain replacements, whereas the other half said they would personally dispose of the batteries or sell them to others as scrap (see graph). The limited knowledge by households about the hazard of not appropriately recycled SHS batteries poses a potential risk for the environment in future.

Figure 29: Disposal of SHS sealed batteries by households



5.3 Energy Impacts

Approximately 4% of the rural population in Uganda is electrified with grid or solar. From the results of the study, in the three sampled districts of Rakai, Bushenyi and Masaka, a coverage rate of 1% of solar electricity can be roughly estimated. On the one hand, these figures highlight the enormous potential for solar energy in the future. But on the other hand, one needs to consider that the impacts of solar energy accrue to only 1% of the rural and mostly richer households. And even for the 1% of SHS users the use of biomass is the most important energy source. 90% of total energy consumption in Uganda is from biomass, with even higher figures in rural areas. This energy mix is not expected to change rapidly. In order to increase the impact of energy projects in general and solar projects in particular, a discussion is needed on how to develop a "social market approach" to reach the "bottom of the pyramid" and how to implement an "integrated energy approach" addressing solar in biomass projects and biomass in solar projects.

5.3.1 Investment in Off-grid Electricity Sources

Although it will be further highlighted that the use of solar systems is more cost effective than other sources of energy, the initial investment costs by far exceed the costs of alternative off-grid solutions like the investment in generators and automotive batteries. Household findings indicate that the initial investment cost of a SHS is 2

times higher than purchasing a generator and 5 times the cost of purchasing an automotive battery (see graph).

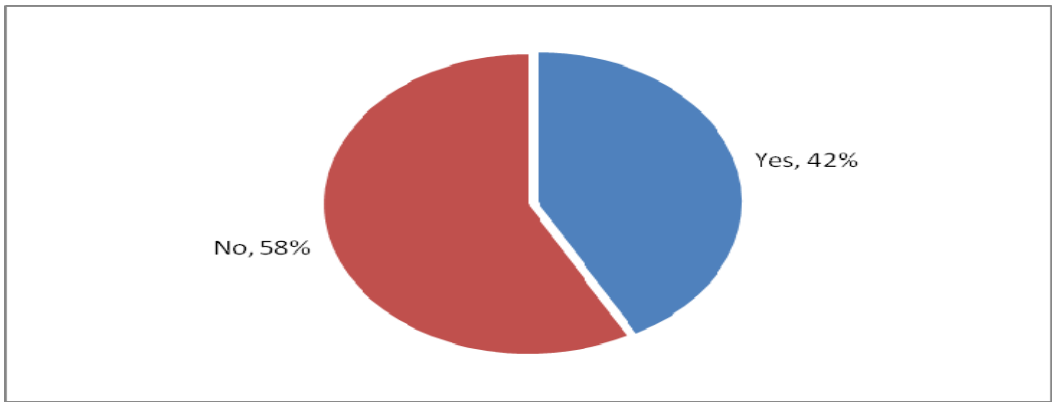
Table 21: Total initial investment costs by energy source

Energy source	Mean (UGX)	Frequency
SHS	650,000	122
Automotive battery	123,714	7
Generator	275,000	2

Calculating the replacement cost of the battery (on average UGX 150,000 with a lifetime of 4 years) and the bulbs (on average UGX 15,000 with a lifetime of 5 months), the monthly running costs of solar systems (UGX 6,125) remain far lower than the costs of operating a generator (UGX 31,000), assuming the lifetime of the solar system and the generator remain the same. This also excludes other maintenance costs such as troubleshooting minor faults and presumes the same service is provided by both sources.

Whereas the investment costs for a solar system appear to be much higher than the average monthly household income (UGX 250,000), access to SHS is facilitated by the availability of micro credit from financial institutions and government subsidies as will be discussed further in the assessment of the development of the rural solar market. Out of the households with SHSs, 58% purchased the systems with the aid of solar loans (see graph).

Figure 30: Households that acquired solar systems using loans



The use of generators, although limited among rural households, is mainly for lighting, charging of cell phones and powering radios and sometimes televisions, while automotive batteries are mainly used for charging cell phones and lighting respectively.

5.3.2 Energy Expenditures

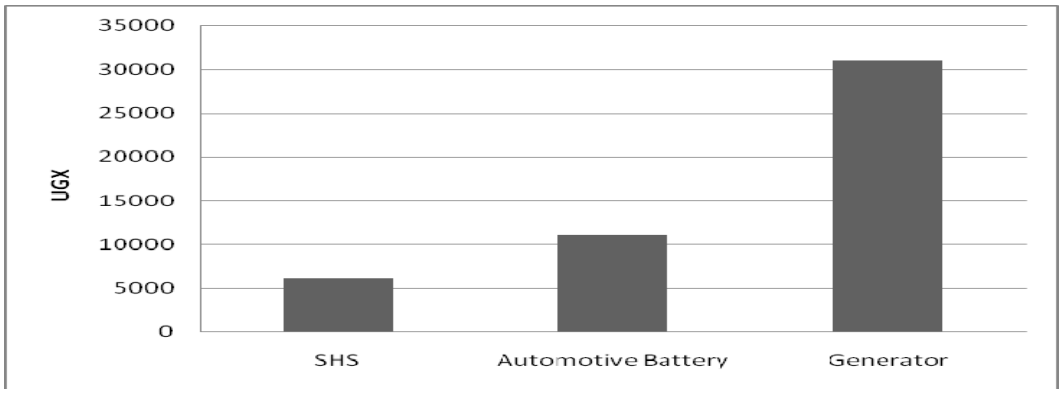
Rural households on average spend a total of UGX 21,000 on energy each month. In line with the finding that biomass is the predominant energy source, expenditures for wood and charcoal represent the highest share. Other energy related expenditures are on kerosene for lighting and dry cell batteries for radios and torches. A comparison of total energy expenditures of households which were grouped according to their use of different off-grid electricity solutions shows that those that use generators spend the highest on energy in a typical month (UGX 31,000) compared to those using solar systems or car batteries (see table). Interestingly however, the total energy expenditure of households with SHS is second highest and on average higher than that for households without any electricity source or those that use automotive batteries.

Table 22: Total monthly expenditure of households on off-grid electricity sources

Electricity source	Mean (UGX)	Frequency
None	18,685	55
SHS	24,650	48
Automotive battery	12,744	5
Generator	31,160	2
Total	21,245	110

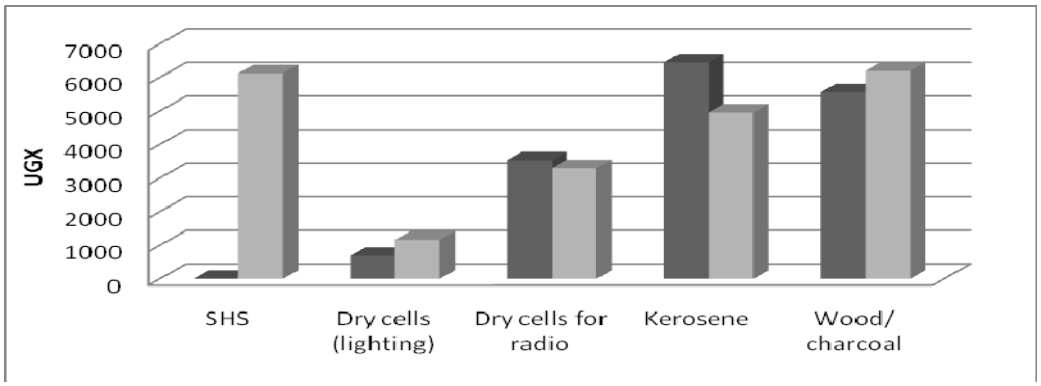
Despite the fact that total energy expenditures of SHS using households are second highest, as mentioned, comparing only the costs for the electricity sources the findings show that solar systems have the cheapest monthly running costs in comparison to batteries and generators (see graph).

Figure 31: Monthly expenditures of users by electricity source[11]



Comparing the energy expenditures for traditional energy sources between the matched sample of SHS users and non users shows slightly higher expenditures among non users than SHS users especially on kerosene (see graph below). Whereas it would appear surprising to have expenditures on kerosene among the SHS users, the stationary nature of the solar light coupled with the fact that not all rooms in the household are lit with the solar system[12] justifies the expenditure on kerosene. Non users' expenditures are represented by UGX 6,500 whereas SHS users spend about UGX 5,000 in a month. Other expenditures (dry cell batteries and wood/charcoal) have minimal differences between the two types of households. These results underscore the fact that the use of solar systems seems to have no impact on the use of dry cells and on cooking, as the SHS users still continue to use traditional sources of energy despite their ascent along the energy ladder.

Figure 32: Average monthly energy expenditures of SHS users and non users



[11] Figures include battery replacement costs for the SHS battery and automotive battery.
[12] Two-light systems in a household with 8 rooms

In line with the finding that households with solar systems do not necessarily climb the energy ladder but continue to use the lower level sources of energy alongside the solar system, it would imply that the maintenance costs on SHSs are purely additional to the existing energy expenditures. A breakdown analysis of the energy expenditures by the users of different energy sources reveals that average monthly expenditure on SHS is higher (on average of UGX 3,000 per month plus the battery replacement cost of about UGX 3,000 per month) compared to expenditures on dry cells and kerosene (UGX 4,300 and 5,700 respectively whereas the replacement cost of torches - UGX 2,500 every 6 months to 2 years - and the replacement costs for the hurricane lantern - UGX 10,000 every one to 5 years - are not included, as the lifetime costs will be calculated separately in section 4.5 Sources of lighting). With this finding, it can be concluded that although the use of solar systems upgrades the quality of energy services and notably the quality of light output it will not significantly reduce energy costs.

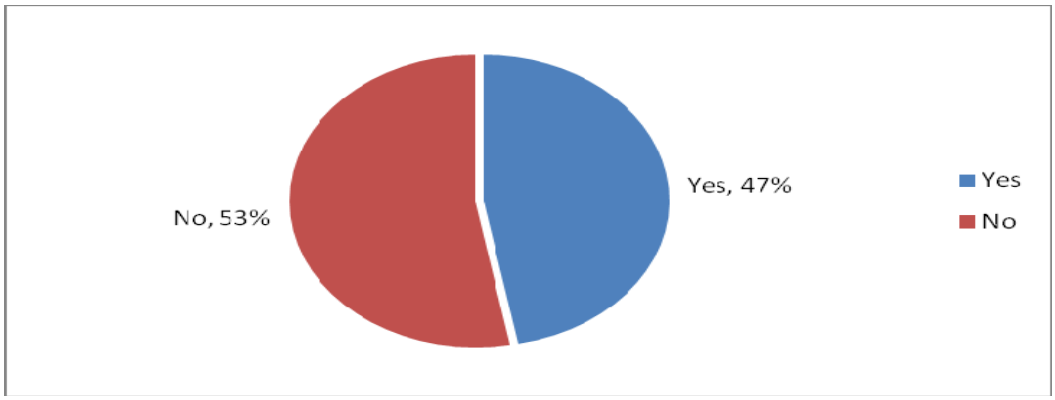
Generally, expenditure on firewood and/or charcoal for cooking comprises the highest energy expenditure for households. On average a family spends UGX 15,000 each month on energy for cooking irrespective of their use of solar systems. Given that SHSs in rural households are mainly used for lighting, the use of a solar system has no impact on a household's expenditure on fuel for cooking.

5.4 Energy Usage

5.4.1 Use of SHS, their Performance and Technical Findings

All the SHSs supplied to households consist of a package of a solar module, a sealed battery, a charge controller and electric bulbs. Also included in the package are the frame, wiring (including cables and switches), battery box and socket for charging. The average size of the systems is 35 Watt peaks (Wp) with - on average - a 30 Ampere hour battery. Out of the sampled SHS users, 53% have never encountered any technical faults with the installed systems, while 47% reported to have experienced problems (see graph).

Figure 33: Households that encountered technical faults with SHSs

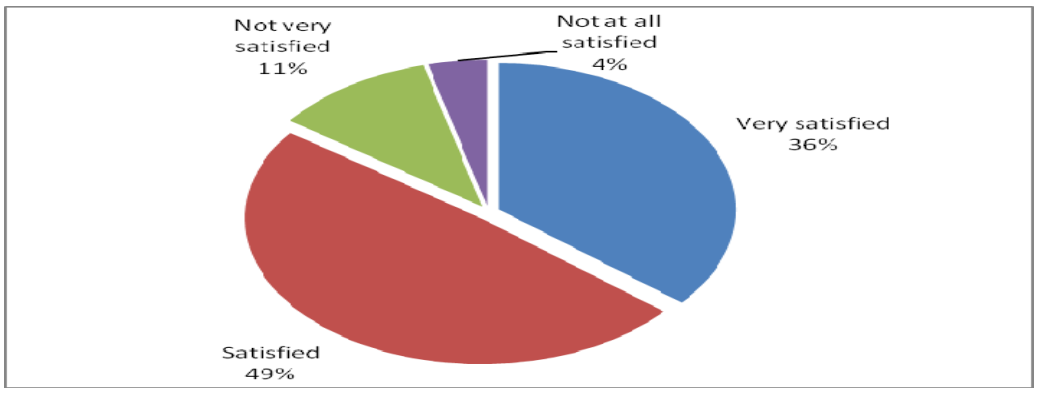


The main technical faults mentioned by households which encountered problems are blown out bulbs (63%), possibly as a result of the weak quality of substitute bulbs, and weak batteries (37%). Considering that the systems supplied are of high quality, it is expected that the trend of having only minor faults will continue.

Out of the households that have experienced technical faults, 94% seek the professional services of a solar technician, usually from the company which installed the SHS. The other 6% opt to fix the problem on their own citing as the reason, that it is cheaper to do own repairs.

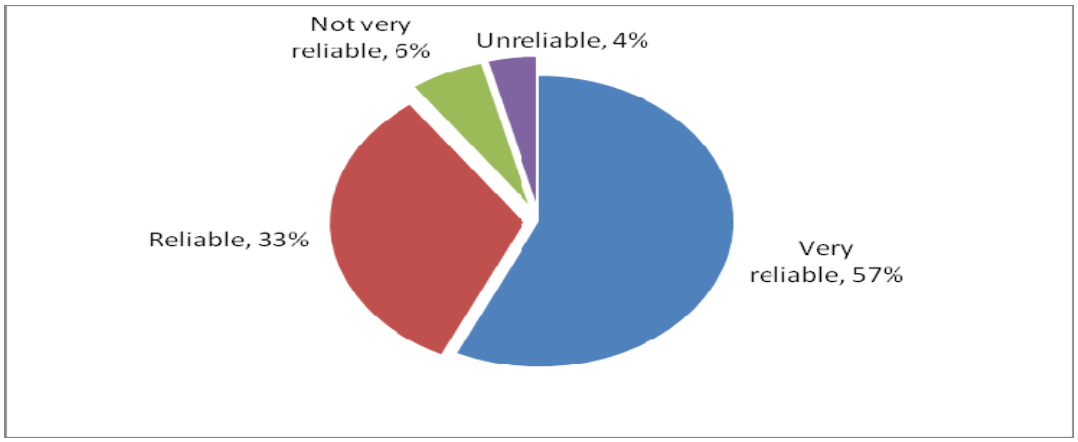
Overall, households are very satisfied with the installed systems with close to 85% rating the systems as reliable and would recommend them to other households (see graph).

Figure 34: Household rating of satisfaction with the SHS



A smaller proportion of households (4%) - whose systems were no longer operational at the time of the assessment - rated the systems as unreliable and are not satisfied (see graph).

Figure 35: Household rating of the reliability of installed SHSs



Improvements to SHSs

With regard to possible improvements to the SHSs, the majority of households (68%) mentioned the boosting of battery capacity and enhancement in the efficiency of the systems to enable the storage of power for longer hours (see table). This finding indicates that most households utilise the solar light to full capacity each evening. Hence, improved capacity of the batteries, and the necessary investment in additional modules which is not fully understood by the users, would lead to more hours of use of solar light. Whereas other recommended improvements are not technical in nature, they seem to point to the pricing of the systems. The mention of the inclusion of an inverter in the SHS package by 10% of the households is also an indication that households, if availed the option at a favorable price, would utilise solar energy for other purposes besides just lighting.

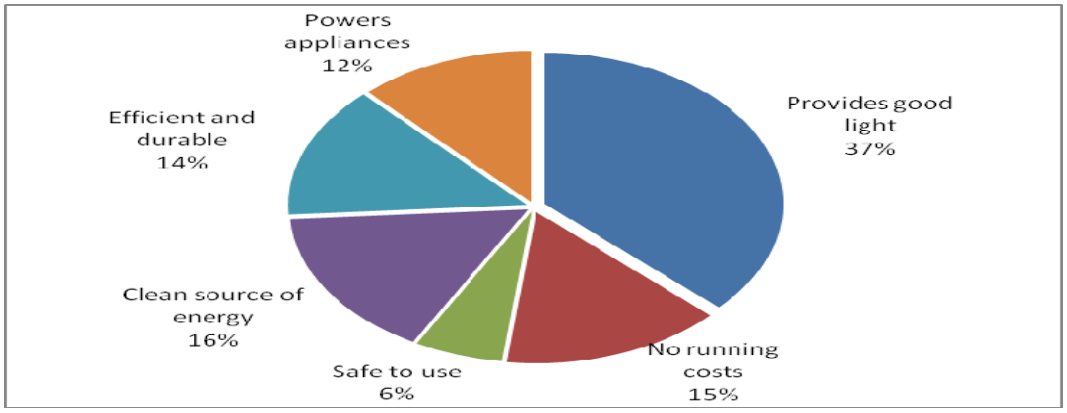
Table 23: Recommended improvements to SHSs by households

Improvements		Frequency	Percent
	Increase battery capacity	62	65%
	More efficient systems	3	3%
	Include an inverter in the package	9	10%
	Increase the number of lights	6	6%
	Reduce the price of bulbs	3	3%
	Increase module size	12	13%
Total		95	100%

Strengths of SHS

The main strength of the SHS, as mentioned by 37% of the households, is its ability to provide good quality light to facilitate completion of activities in the evening. Other strengths mentioned include that solar energy is a clean source of energy (no soot or emission of smoke), efficiency in reducing lighting costs, the durability of the systems and their ability to power appliances such as radios and phone chargers (see graph). Despite the fact that solar energy is not used for cooking, it still enables the process by providing good quality light.

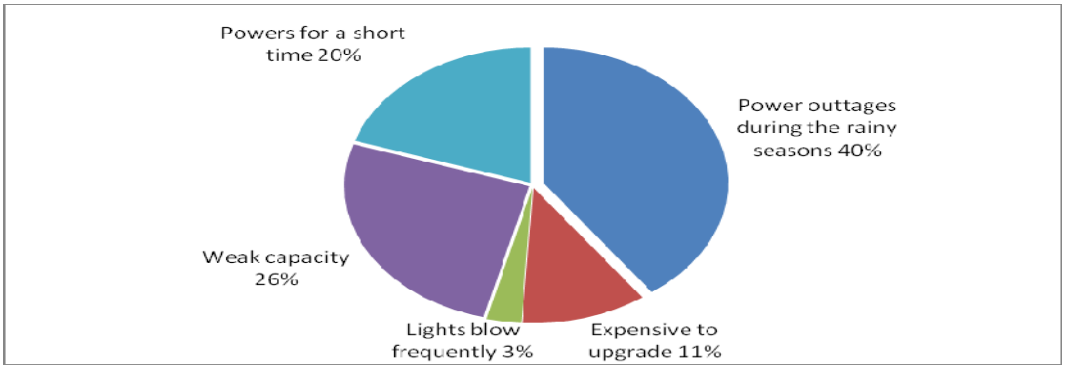
Figure 36: Strengths of the SHSs



Weaknesses of SHS

The weaknesses of the SHSs on the other hand - as expressed by the households - include reduced energy generation during the rainy seasons, the weak capacity of the batteries to store enough power - causing the system to light for less hours than expected - and the blowing out of bulbs respectively (see graph). Besides the reliance of the SHSs on the weather, other weaknesses mentioned point to the need for SHS users to be fully aware about the capacities of the installed systems to ensure that the systems are not overloaded.

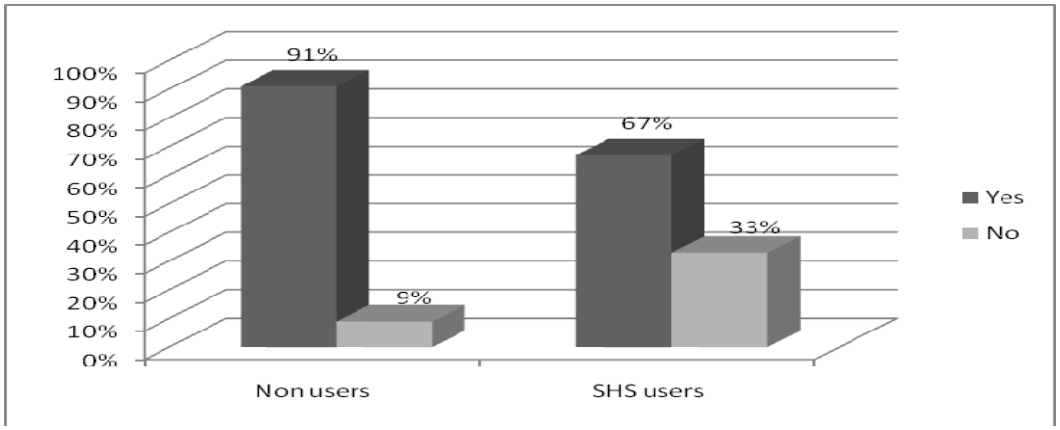
Figure 37: Weaknesses of the SHSs



5.4.2 Use of Kerosene

The majority of rural households represented by 67% of the SHS users and 91% of the non users use kerosene for illumination (see graph). On average, the users consume 2.4 liters in a month, while the non users utilize 3.2 liters in a month. This implies that the use of solar systems only reduces the kerosene consumption by little more than half a liter in a month. In line with the findings in previous sections, kerosene use does not greatly reduce following the installation of a SHS owing to customs and habits, the stationary nature of the lights and the fact that not all rooms in the household are lit. Kerosene use among households with solar systems thus continues and is mainly for lighting the kitchens which are adjacent to the main house and other rooms which are not connected to the solar system.

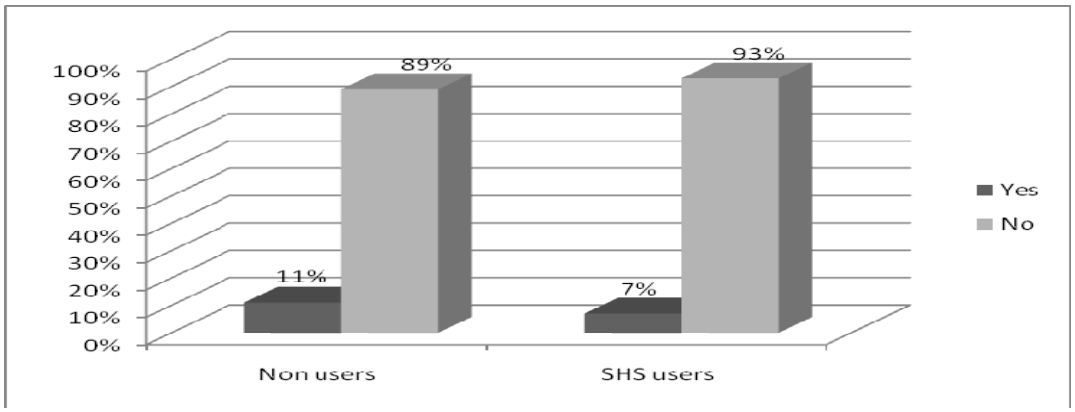
Figure 38: Household use of kerosene for illumination



5.4.3 Use of Candles

The majority of rural households do not use candles as a source of energy. Over 90% of the sampled households do not use candles for lighting (see graph). Among the users of candles still, the use is on average 2 candles per household in a month irrespective of their use of SHS. The limited use of candles could be attributed to the fact that they burn out quickly and become an expensive lighting source in the long run. The light output is also restricted to a smaller area compared to the kerosene lantern and are therefore not preferred.

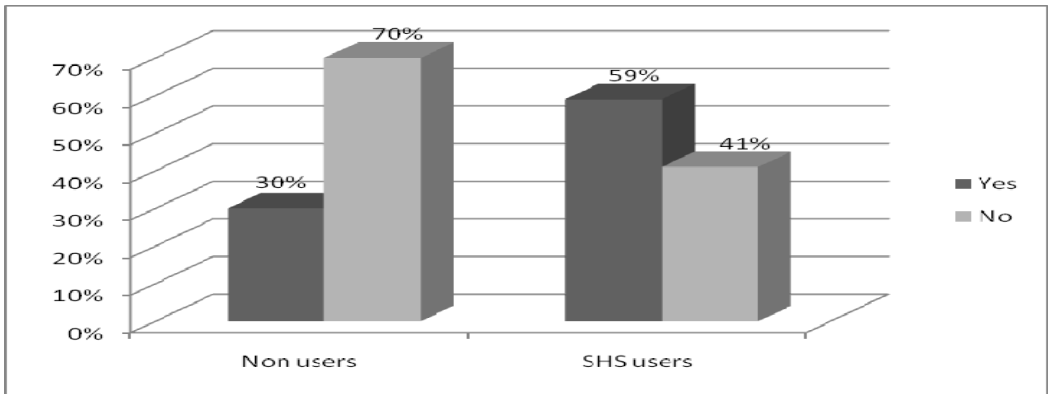
Figure 39: Household use of candles for lighting



5.4.4 Use of Dry Cell Batteries

There is more use of dry cell batteries for lighting among the SHS users than the non users represented by 59% and 30% respectively (see graph). This could be explained by the fact that the SHS users have to use temporary light to move to places that are not lit by the solar system. It could also imply that SHS users are more accustomed to electric light and require the use of torches for movements at night compared to the non users. The findings however show no significant difference in the quantity of dry cell batteries used for lighting by SHS users and non users, with both types of households using on average 1 pair per month.

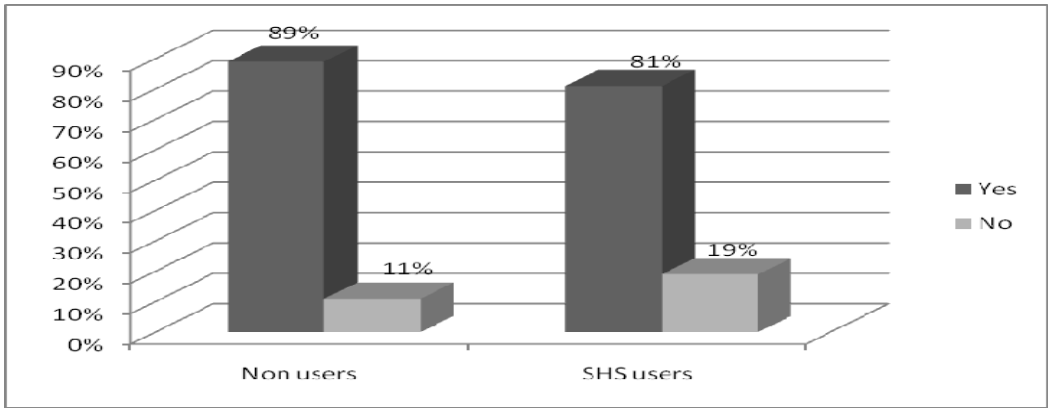
Figure 40: Household use of dry cell batteries for lighting



In regard to the use of dry cell batteries for radio, over 80% of both SHS users and non users use dry cell batteries for radio (see graph). As it will be subsequently mentioned in later sections, most households own small radios which are powered by dry cell batteries. Among the SHS users, it was found that some households have radios whose voltages are incompatible with the output of the SHSs, whereas other households had systems that could power the radios, but lacked additional cable wiring that is not supplied as part of the SHS package. Many radios do not have a socket and are designed for battery use only.

The quantity of dry cell batteries used for radio is the same for both the SHS users and non users and is on average 4 pairs per month. It can thus be concluded that after 2 years of use, the solar system had no impact on the use of dry cell batteries by households.

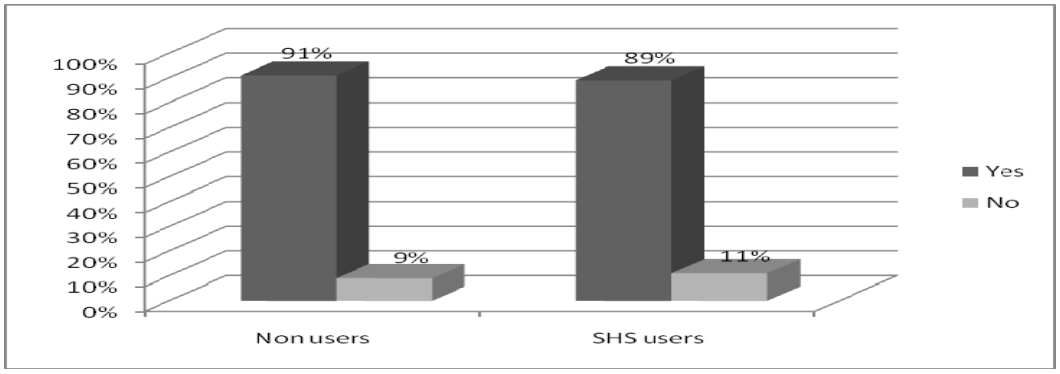
Figure 41: Use of dry cell batteries for radio



5.4.5 Use of Wood/Charcoal and LPG

Rural households generally use wood as the main fuel for cooking represented by an average of 90% of both the SHS users and non users (see graph). On average both types of households utilize 3.5 bundles of wood each week (14 bundles a month) for cooking. The usage of charcoal by households for cooking is rare and at 5%, of which roughly half a sack is used in a single month. As demonstrated previously there is not much difference in the use of energy sources for cooking between households using wood and charcoal, but wood is more popular. Although some of the wood is collected and hence is for free, many households buy additional wood alongside collected. None of the sampled households uses gas for cooking. These findings underline the fact that SHSs have no impact on the use of energy for cooking.

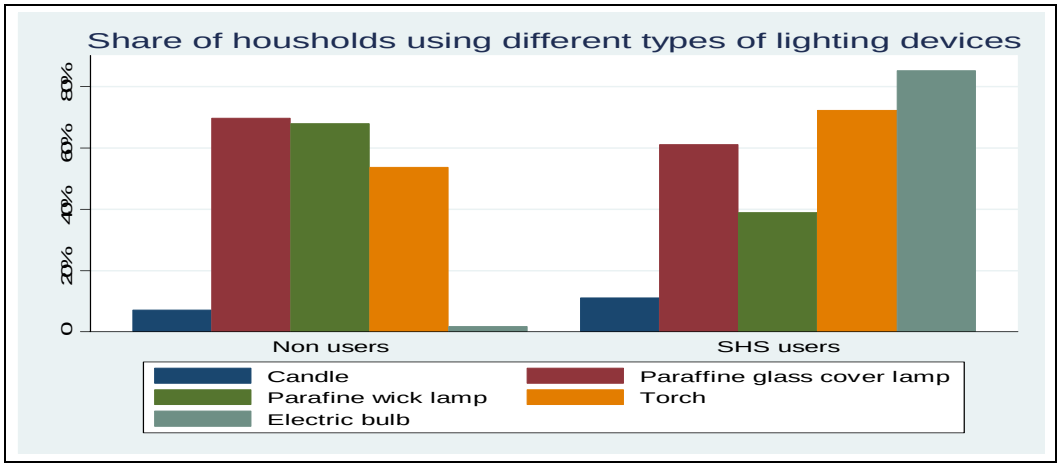
Figure 42: Household use of wood for cooking



5.5 Sources of Lighting

Among the SHS users, the major types of lighting devices used by rural households are electric bulbs whereas paraffin glass cover lamps and paraffin wick lamps are the most common devices used by households without SHS (see graph). The findings also show more use of torches among the SHS users than the non users probably due to the fact that SHS households get used to electric light and use torches in places not lit by the system. Despite the use of solar systems it is apparent that households continue to use other traditional sources of lighting.

Figure 43: Share of households using different types of lighting devices



On average the households with solar electricity use 3 bulbs for lighting and 1.5 paraffin glass cover lanterns and paraffin wick lamps. In contrast the households without solar systems do not use bulbs, but use on average 2 paraffin glass cover and 2 simple wick lanterns per household - slightly more than the SHS users although the difference is negligible. On the other hand, both SHS users and non users on average use one torch per household.

The table below summarizes the costs and lifetime, estimated by the households, of the various lighting devices used by households. The lifetime cost per hour light is highest for torches (about 200 UGX) and lowest for simple wick lamps (about 30 UGX) whereas the light output of simple wick lamps is lowest (about 10 lumen) and highest for an electric bulb (250 lumen) whose lifetime costs, can be estimated at

UGX 46, if it is powered by a 3 light solar system with a lifetime of 20 years and whose battery needs to be replaced after 4 years.

Table 24: Lifetime cost per hour light of lighting devices used by households

Lighting device	Cost (UGX)	Lifetime (Months)	Hours of light per day- SHS users	Monthly running costs	Lifetime cost per hour of light (UGX)	Lumen per hour (rough estimate)
Paraffin glass cover lamp	10,000	12	2.5	1,666	33	60
Simple wick lamp	1,000	3	2.5	1,666	27	10
Dry cell battery torch	2,500	6	0.25	1,000	189	10
Energy saver 7 watt (electric)	15,000	3 – 36 (average 15 depending on quality	3.5	2,042	20	250
SHS battery replacement	150,000 for 3 lights	48				
Total system	650,000	240		2,708	26	

As it will be further demonstrated, calculating the light output costs in lumen, solar light is the cheapest. This means that although total expenditures for lighting are higher in SHS using households due to their continued use of traditional lighting sources they pay less per unit light output than non users. Put simply, not only is the light quality much higher in SHS households, but also costs per unit of light are lower than in households without SHS.

5.5.1 Lumen Hours

Lumen hours provide a standardized measure of the light output for the various lighting devices. Comparing the total household expenditures on the assorted sources of lighting (electric and traditional) with the total lumen hours per month in order to draw a realistic picture of the lighting situation in households on the ground, gives the finding that: Including all lighting devices, on average, SHS users spend UGX 0.3 per lumen hour (battery replacement costs and investment costs are included and apportioned on a monthly basis) which is less than half the expenditure by the non users of UGX 0.7 per lumen hour (see table).. Owing to the efficiency of electricity and the proportionate higher cost of kerosene, the non users, who use only traditional

paraffin lamps, spend more per lumen hour to obtain the same quality of light than the users, who use electric bulbs in addition to kerosene lanterns.

Table 25: Household total expenditures on lighting and total lumen hours per month of all lighting devices used

	Mean (UGX)	Lumen hours
Non users	7,078	10,886
SHS users	18,275	71,607

5.5.2 Use of Lighting

With the aid of the above mentioned lighting devices, households with SHS on average use artificial light for 3.5 hours per day, while the non SHS users use light for 3 hours (see table). This implies that on average, households with solar systems use light for half an hour longer than their counterparts without solar systems. The lights are mainly used in the evenings between the hours of 19:00 and 22:00 respectively. Artificial lighting is rarely used by households at dawn.

Table 26: Total hours of use of artificial light per day

	Mean (Hours)	Frequency
Non users	3.0	56
SHS users	3.5	52
Total	3.3	108

The SHS users typically light electric bulbs for 3.5 hours a day, supplemented with paraffin glass cover lanterns and simple wick lamps that are lit for 2.5 hours each. In contrast, households without solar systems mainly light paraffin glass cover lanterns for 3 hours alongside simple wick lamps which are also lit for 3 hours. On average, households without solar systems use paraffin glass cover lanterns and simple wick lamps for half an hour longer than SHS users. These findings reinforce the conclusion that household use of solar systems does not eliminate the use of traditional lighting devices, but will lead to a reduction in the number of traditional devices used and the hours of use, although not to a great extent.

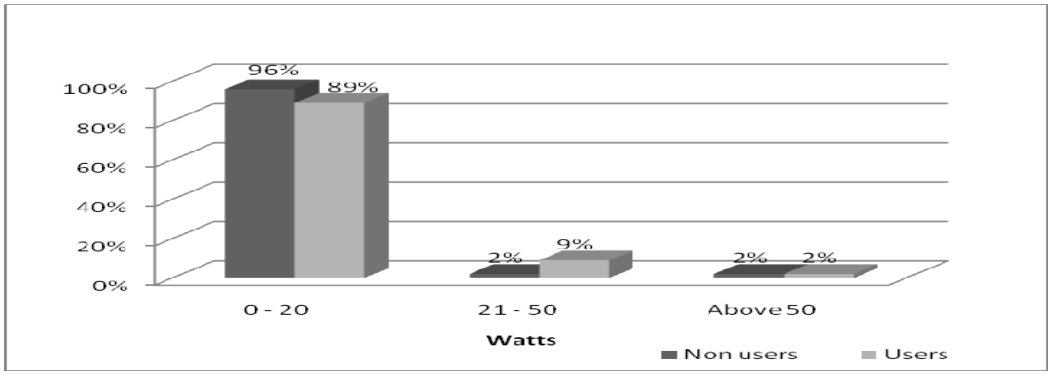
Table 27: Hours of lighting of different types of lighting devices

		Mean (hours)	Frequency
Non users	Paraffin glass cover	3.0	56
	Simple wick lamp	3.0	56
	Energy saving electric bulb	0	56
SHS users	Paraffin glass cover	2.5	54
	Simple wick lamp	2.5	54
	Energy saving electric bulb	3.5	54

5.6 Use of Electric Appliances

The main electric appliance used by households is radio. All the sampled households use at least one radio within the household which is used during the day for about five hours irrespective of whether solar systems are used or not. Typically, rural households use small radios of less than 20 watts represented by over 90% of all households. Only 2 of the sampled households owned radios consuming more than 20 watts (see graph). These radios are powered by SHSs. Considering that the majority of radios are small and are powered by dry cell batteries, it can be concluded that - in the short run - the use of solar systems has no influence on the use of radios by rural households.

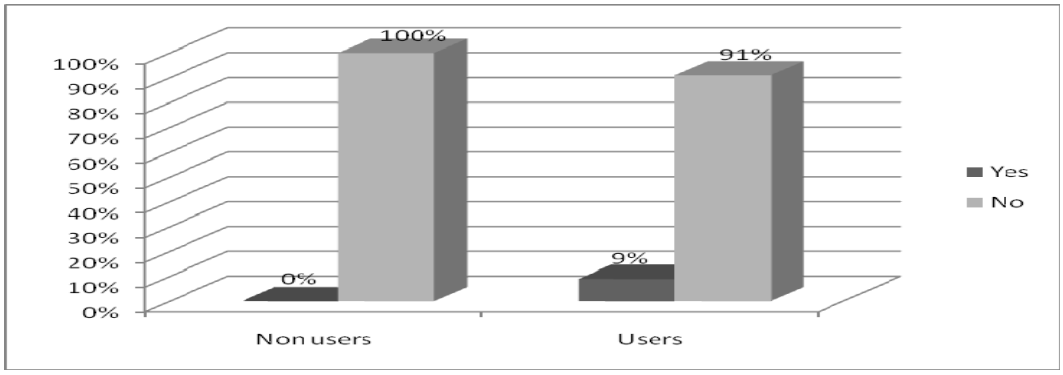
Figure 44: Power consumption of radios used by households



With regard to television, only 9% of the sampled households had televisions, all of which were SHS users. The average hours spent watching televisions are 3 hours in a day. The limited use of televisions can be attributed to the low capacity of the

installed solar systems. Besides radios and cellular phones which are discussed in the next session, no further electric appliances are used in rural households

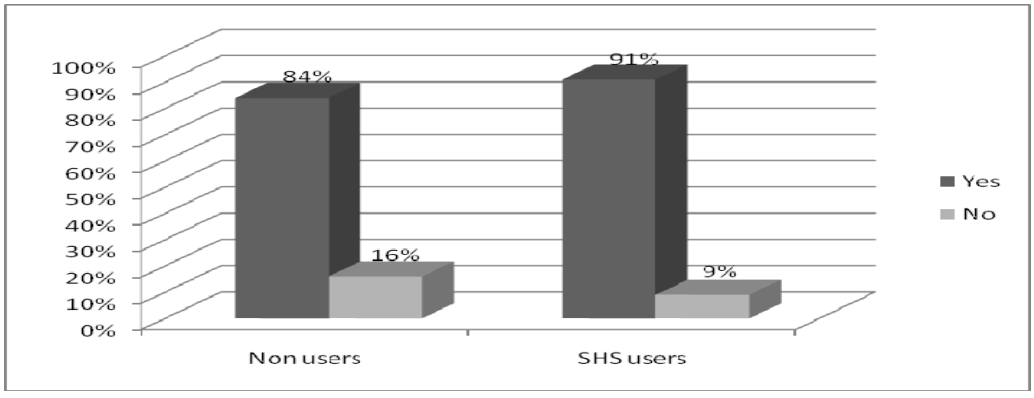
Figure 45: Household use of televisions



5.7 Use of Cellular Phones/ Telecommunication

Over 85% of the households have at least one cell phone irrespective of their use of solar systems (see graph). On average households with solar systems have 2 phones, while those without SHS have 1 phone. A further analysis of only farmers confirms this finding with (on average 2 phones among the SHS users and 1 phone among the non users). This finding could be attributed to the availability of a cheap and convenient source for phone charging provided by the solar system.

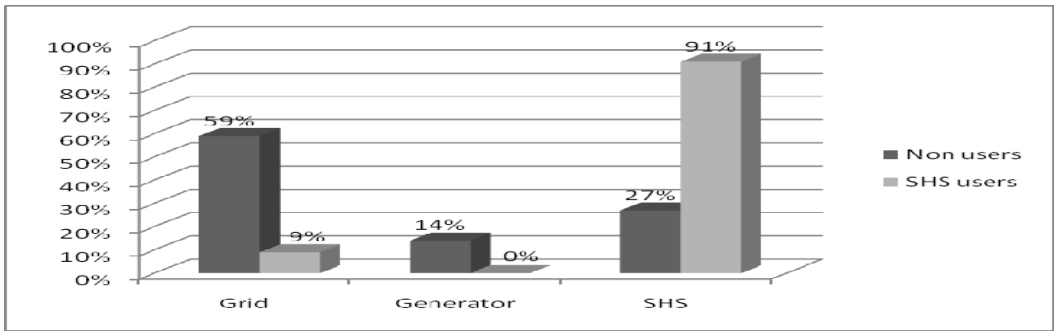
Figure 46: Cell phone use by households



Nearly all the households with SHS (90%) are able to charge their cell phones using the SHS with the remaining 9% charging with grid electricity at nearby trading

centres or major towns. In contrast, the majority of households without solar systems (59%) charge their cell phones using grid electricity at nearby trading centres or at neighbour's premises or commercial businesses that charge using solar energy represented by 27% (see graph). It costs on average UGX 500 to charge a phone each time. Thus the use of solar systems enables households to reduce their expenditure on phone charging of about UGX 3,000 a month, coupled with the costs of transportation to and from the place where the phone is charged each time.

Figure 47: Energy source used to charge phones



On average, the household heads with SHSs spend more on cell phone credit each month than the non users. In line with the finding that SHS users are more engaged in the formal service sector, these results are to be expected. On average the SHS users spend twice as much on cell phone credit each week than non users (UGX 10,000 and UGX 5,000 respectively). The findings however show no difference between the expenditure on cell phone credit by women between the SHS users and non users (see table).

Table 28: Weekly expenditure on cell phone credit by gender

		Household head	Spouse
Non users	Mean (UGX)	5,063	3,200
	Freq	56	56
SHS Users	Mean (UGX)	10,269	3,945
	Freq	54	54
Total	Mean (UGX)	7,618	3,566
	Freq	110	110

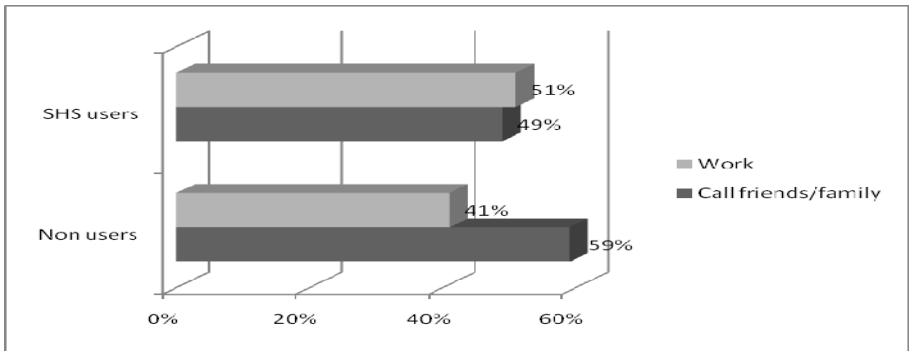
A further comparison of only farmers with and without solar sytems shows nearly the same results. Household heads among the SHS users spend close to twice the amount spent by non users on cell phone credit per week (UGX 6,395 and UGX 3,889 respectively). There is however a wide disparity between the women from households with and without SHS with the former spending five times more on cell phone credit than the non users (UGX 2,000 and UGX 396 respectively). These findings underscore the fact that access to a phone charging facility is likely to promote cell phone use; while non users, have to pay to have their cell phones charged each week in addition to purchasing cell phone credit.

Table 29: Weekly expenditure on cell phone credit by gender for farmer households

		Household head	Spouse
Non users	Mean (UGX)	3,889	396
	Freq	27	27
SHS Users	Mean (UGX)	6,395	2,000
	Freq	19	19
Total	Mean (UGX)	7,618	3,566
	Freq	46	46

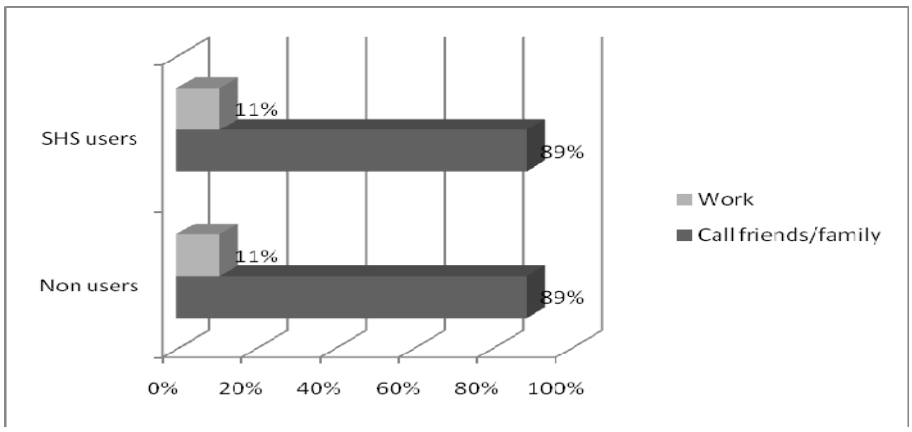
In line with the findings on the ownership and use of cell phones, the majority of SHS users (51%) mainly use their cell phones to facilitate their work, while the reverse is true for non users. Close to 60% of the households without SHS use their cell phones mainly to communicate with friends and family members (see graph). It can therefore be concluded that the availability of a phone charging facility contributes to the work efficiency of SHS users.

Figure 48: Major use of cell phones by household heads



In contrast, the findings show no difference in the use of cell phones by women between the SHS users and non users (see graph). Nearly 90% of all the women with cell phones use them mainly to communicate with friends and family as opposed to facilitating work. This is in line with the finding that the majority of women in rural households are housewives who are also engaged in agriculture.

Figure 49: Major use of cell phones by women in households



6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the impact assessment on households, the following conclusions are drawn:

- **Take up**: The SHS take up rate of rural households is very low and more widespread among wealthier and better educated households whose main occupation is in the salaried employment and commercial sector rather than agriculture. This seems to be due to the perception that farmers benefit less from SHS as well as the high investment costs. Only about 5% of non electrified households state lack of electricity as a major problem whereas the most pressing problem that households are coping with is lack of income to meet basic household expenditures (50%).

- **Main use**: The main use of SHS is for electric light. Apart from cellular phones and very few radios, televisions and no other electric appliances are used.

- **Income**: The availability of SHSs and electric light does not lead to an increase in productive activities in the evening and hence has no impact on household incomes. Only a small share of rural households and irrespective of their use of solar systems engages in productive income generating activities in the evenings. However, the convenience and quality of the productive and domestic work for those that do such work is increased.

- **Education**: The use of solar systems increases the number of children studying in the evenings and the hours of study by an extra hour for the users due to the better quality of light which, in the long run, might have an impact on the level of education.

- **Gender**: As domestic work in the evenings is facilitated through electric light more women in households with a SHS work in the evenings and for longer hours than women in households without solar systems.

- **Health**: The incidence of respiratory tract related illnesses among households is similar irrespective of their use of solar systems. This is because the main indoor air pollution results from inhalation of fumes from firewood and charcoal used for cooking. Considering that solar energy is not used for cooking, the use of SHS has little impact on health. Nevertheless children of households without solar systems suffer slightly more often from respiratory illnesses due to their studying with kerosene lanterns.

- **Environment**: The use of SHS has virtually no impact on carbon emissions as households continue to use traditional energy sources and do not significantly reduce their consumption of kerosene. The inadequate knowledge by some households on the proper disposal of the SHS batteries after their lifetime could pose a potential threat to the environment.

- **Energy**: Despite the use of solar systems, households do not climb the energy ladder but continue to use traditional forms of energy alongside solar PV. As a result of this, there is no reduction in total energy expenditures but rather additional replacement costs for bulbs for SHS using households.

- **Telecommunication**: The use of solar energy facilitates telecommunication by providing a free source of power for charging phones at the households, thereby saving on costs for charging at public places and transport to such locations. Nevertheless, irrespective of the use of solar systems all households possess and use at least one cell phone.

- **Electric appliances**: SHSs have very little impact on the investment in and use of electric appliances by rural households since the majority of installed systems are either limited in capacity (on average 35 Watt peak) or unable to power electric appliances. Very few TVs and radios were found that are powered by solar PV,

although a grand majority of households irrespective of the use of solar systems use dry cell powered radios.

- **Performance of SHS**: About 90% rate their solar system as a reliable source of electricity whereas the weakness is said to be the low capacity and blown out bulbs.

- **Main benefit**: SHSs mainly benefit children within households because they facilitate the completion of homework. While the male interview partners said that also women benefit more than men because of the electric light that facilitates household chores after sunset, it should be left to the women to judge if the increased hours of work are considered to be a benefit or an increase of their workload.

6.2 Recommendations

In order to enhance the GTZ-PREEP objectives for households, the following activities are recommended:

1. Increase the Take-up Rate - Enhance Dissemination by Focusing on the Poor:

- GTZ supported solar companies and promotion of SHSs in rural areas should focus on smaller systems (35 watt peaks and less) which are affordable for poor rural households. In order to attain the objective of higher dissemination rates, awareness needs to be raised notably among farmers as they perceive little use for solar systems but whose children would also benefit as much as the children of people engaged in commerce and salaried employment. Although in the short run it is legitimate to take the upper class of wealthier and better educated households as an entry point to develop a sustainable rural solar market, in the long run development cooperation projects in general and market based approaches in particular should reach the “bottom of the pyramid” and the “mass of the poor”. This might be achieved through a “social market approach” which includes “complementary awareness and education services”.

2. **Improve the Performance of SHS:**

- High quality user training on system limits, quality of components (esp. bulbs) and identification and trouble shooting of minor technical faults of the SHS should be provided. This would reduce monthly maintenance costs, prolong the lifetime of bulbs and functionality of the systems, hence increasing their impact and the satisfaction of the households.

3. **Bring Down Energy Costs and Reduce the Use of Traditional Energy Sources:**

- Installation of solar systems and wiring of rooms should prioritize the places where the light is used most on a daily basis. This would help reduce on the energy expenditure for households with solar systems that continue to use kerosene for lighting places not reached by the SHS.

- Raise household awareness on the need to minimize expenditure on dry cells for lighting and radio that can be substituted by better utilization of the SHS. Users should be informed and trained about options to use the radio and rechargeable torches with the solar system e.g. charging and using the radio with solar PV to cut down expenditures on dry cell batteries. This includes obtaining the necessary wiring/compatible radios, battery chargers and rechargeable batteries that can be powered by the system.

- Raise household awareness on avoiding the use of kerosene for lighting places where the solar system can be used and in places where the light is not very necessary. The awareness should propose creative solutions such as the use of "one bulb in two rooms" (a bulb hanging from the ceiling above the wall can be used in two rooms by using a long cable attached to a pivoting "crane system").

4. **Increase the "Energy Impact" Through "Integrated Solar Stove Approaches":**

- Implement "integrated energy projects" combining solar PV and improved stoves activities in order to increase the energy impact. On the one hand, biomass accounts for the highest energy expenditures of rural households and is

responsible for severe health effects notably on women. On the other hand lack of electric light hinders studying of children in the evenings while also representing high costs for kerosene and dry cells. Integrating improved stove promotion in solar projects and solar promotion in improved stoves projects has minimal additional costs but has a huge potential to increase the "energy impact" (e.g. improved stoves builders could get an additional half-day training on solar PV and a contact to a local solar dealer in order to raise awareness within their community of operation and to promote "first step stove, second step solar"). Since GTZ's improved stove project is a success story in Uganda, the "integrated energy approach" holds the potential to reach the "mass of the poor". The participating solar companies should e.g. agree in the PPP contract to promote stoves to their clients and raise awareness as part of the user training. They would network with local builders to promote "first step solar, second step stove".

7.0 SOLAR MARKET ASSESSMENT

The assessment of the development of the solar market involved a comparison of the rate of installed SHSs in the treatment and the control region in order to evaluate the impact of the GTZ support on the dissemination of SHS. But while it might turn out that the number of installed systems in the GTZ supported region is much higher than in the control region, the growth of the solar market today may have declined and is likely to decline further if it is not supported in a sustainable way. In this case, one might argue that the market based approach failed as much simpler projects like the mere distribution of solar systems by the government or international donors would have had the same dissemination impact. In consequence, in order to determine if a sustainable market has been developed, the proxies that have been considered in the assessment of the solar market include:

- the number of active local solar companies,
- the employment effect on notably solar technicians
- finance institutions providing loans for solar systems
- the current number of installations per year; and
- the expected number of installations in the coming year..

7.1 The Impact of the GTZ Support in the Opinion of the Solar companies

Within the Public Private Partnerships with GTZ, the three solar companies received management, technical, financial and marketing training as well as direct support for establishment/improvement of outlets, demonstration kits, local transport, advertisements, radio and talk shows among others. Furthermore, GTZ supported the companies to enter into partnerships with local microfinance institutions including Savings and Credit Cooperatives (SACCOs). The marketing strategy was funded on a matching grant basis (50:50) and hardware in form of motorbikes and demonstration equipment were provided.

In line with the widely known fact that business in rural Africa is hard, the three supported solar companies also mentioned that they might not have developed their rural solar branches if they had not been supported by international donors including

the GTZ PREEE Program. Although already active in the solar business within Kampala, the decision to invest in rural solar infrastructure was not self-evident. Further consultations with the Rural Electrification Agency (REA) confirmed that solar companies up to today have not developed the rural solar market on their own initiative. Since they became active in Uganda in the early 1990s as a result of international programs which funded the dissemination of solar PV, the development of rural branches was almost always project and donor driven. The lack of financial and technical capacity, high upfront costs and access to basic infrastructure in rural areas are still existing barriers hindering solar companies from developing rural markets without support.

Solar Energy Uganda (SEU) stated that the GTZ support was essential to enter the market. It was very timely because it was given at a time when SEU had a great need for funding to expand the market. In addition to the GTZ support, during phase one of the Energy for Rural Transformation Program (2003) implemented by the World Bank, SEU received business assistance and grants on imported equipment. While the funding from other donors ended in August 2008, the manager said that: “It helped us to achieve our objectives and targets.”

Ultrasolar, in addition to the GTZ support, received a USD 35,000 credit from the American organization E&Co to invest in stock. For Ultrasolar, it would not have been possible to develop the business as aggressively as it did without this substantial external support, but the credit application was facilitated by GTZ. Thus the manager of Ultrasolar is also of the opinion that the support of international donors including GTZ was essential to enter the rural solar market in a sustainable way.

Incafex, in an undefined way, also received support from international donors. But although important, the support was stated not to be a pre-condition to develop the rural solar business. Nevertheless, since GTZ supported Incafex the local agent reported that notably the technical skills’ training – which is key in the development of a sustainable solar business - became better in terms of quality.

7.2 Solar Market in Bushenyi

The main focus district for Incafex is Bushenyi. The total number of systems installed by Incafex since project start (Feb 08- Feb 09) is 169 whereas 99 systems are installed in the focus sub-counties selected for this assessment (Kyamuhunga and Bugongi). With a population of 16,000 households, the coverage for Incafex SHSs is 1 system per 162 households. Considering an estimated market share of 70% in Bushenyi - according to Incafex management- one can estimate that the actual coverage in the focused sub-counties is 30% higher which means 1 system per 124 households, an equivalent of an achieved coverage of 0.8% newly installed systems by all active solar companies since project start.

Since project start in February 2008, most of the SHSs sold by Incafex have capacities of 12 to 14 Watt peak, with a few 50 and 75 Watt peak as well as 100 Watt peak systems. In total, around 120 Systems were sold in Bushenyi district in 2008. Despite the high sales figures at project start, the market for high quality solar systems is - according to the local agent - already showing signs of saturation. Richer households are creamed off and the poorer ones cannot afford the high quality solar products. Although there is a general trend towards solar, the demand for quality SHS in the initially focused sub-counties is decreasing. As Incafex mainly provides quality solar products, total sales are decreasing and expected to decrease further (see table for details).

Typical solar systems sold (Wp)	Sales price of complete system (UGX)	Profit margin	Current Monthly sales	Reported average monthly sales in the last one year	Systems sold in the last one year	Projected sales for 2009
12	450.000	30-50%	5	10	70	100
14	600.000	29%	5	8	20	
50	1.4 million		2	5	15	
75	1.8 million		2	3	15	

The solar market for Incafex might shrink by 17% as the total number of installed systems is expected to fall to around 100 systems in 2009. In consequence the local agent is considering opening his product range for lower quality but cheaper products. Nevertheless Incafex will continue its rural solar business and its quality based

business strategy as clients are well informed about the lower quality they purchase if they want to spend less.

The market share of Incafex in Bushenyi district is estimated to be 70% whereas SEU has 20% and two smaller solar suppliers, Unisolar and Energy Solar (not GTZ supported), each have 5 % of the market share. The difference between Incafex and other non GTZ supported solar companies operating in the district was said to be the fact that Incafex, for up to now, only provided quality products (panels from European companies, sealed batteries, and quality charge controllers) that were tested and installed by professional technicians with professional after sales services. It was stated that: “Incafex - with the help of GTZ - has well trained technicians. Other companies do not have them, that’s what makes the difference!”

While the initially focused sub counties are served by four solar companies, no company is operating in the control sub counties where no initiatives to develop the rural solar market have been undertaken. In spite of this, sparse households within the control sub counties have installed SHSs supplied by three other companies - Iron Electricals, MK Systems and KK Solar Supplies – which are based in Mbarara town (about 60km from Bushenyi). The absence of locally based companies could explain the low take up rate of solar PV in the control region, with only the well informed and rich households installing systems at their own initiative.

The prevalence of SHSs installed in the treatment region is further facilitated by the existence of financial institutions that provide loans for solar systems. Out of the 5 SACCOs operating in these sub counties, 2 offer solar loans, while none of the 4 SACCOs in the control region offers solar loans. In the past year alone, over 40 solar loans have been disbursed in the treatment region and the number of loans is expected to grow.

There are 8 solar technicians in the project area, 2 of who work for Incafex. All the 8 technicians are based in Bushenyi town, and traverse the sub counties of the districts making installations and repairs for clients. In contrast, owing to the undeveloped solar market, there are no local technicians based in the control region. An unspecified number of technicians from the 3 solar companies in Mbarara are

however said to occasionally carry out system installations and maintenance for their clients.

7.3 Solar Market in Masaka

To develop its rural solar business UltraSolar's[13] main focus is Masaka District. Ultrasolar Masaka, a franchisee of Ultratec, has installed a total of 210 systems since project start (Feb 07 –Feb 09), 92 of which are in the three focus sub counties of Masaka (see below). The total population of these sub counties is 17,710 households implying coverage of 1 system per 193 households for UltraSolar solar home systems. Considering a market share of 80% for UltraSolar (see below) one can estimate that the actual coverage in the sub counties of operation is 20% higher, represented by 1 system per 161 households which corresponds to coverage of 0.6% of all households.

UltraSolar started its solar business in 2006 with the help of international donors (notably with the support of Shell Foundation and later in 2007 with the support of GTZ). The district of Masaka and notably the areas of Lwamaggwa and Kyotera were initially focused, but owing to potential demand in the neighboring districts of Lyantonde and Sembabule, more focus on marketing was done there. In 2006, 40 systems were sold. In subsequent years, sales have been increasing steadily to 60 systems in 2007 and 100 systems in 2008, and are projected to double to 200 systems during the following 12 months.

UltraSolar's area of operation, in comparison to the focus area of SEU and Incafex, is much larger. This might be due to the more independent mode of operation (franchising) and the decentralized management. UltraSolar's market share is estimated to be 80% in Masaka whereas SEU is believed to occupy 10% of the market and Incafex, together with Instant Power Distributors (not GTZ supported) another 10%. Being a franchise of Ultratec - one of the at least 7 solar importers in Uganda (Italtrade, SEU, Konserve Consult, Dembe, AB Matra and Ase Solar) - UltraSolar only sells approved quality products, installs systems with their own trained technicians and provides professional after sales services. It offers a range of different

[13] UltraSolar Masaka/Nacosolar Ltd. is a franchisee of the Kampala-based company- Ultratec. GTZ supports Nacosolar through a PPP contract with Ultratec.

solar products and mainly sells one, two, three and four light systems with capacities from 12-100 Wp. Nevertheless, an increasing number of larger systems (50-100 Watt peak) have been sold recently (see table for details).

Typical solar systems sold (Wp)	Sales price of complete system (UGX)	Profit margin	Current Monthly sales	Reported average monthly sales in the last one year	Systems sold in the last one year	Projected sales for 2009
10	260.000	50%	6	5	98	200
14	455.000		4	3		
24	500.000		1	6		
24	670.000		1	4		
50	1.6 million		2	3		
55	1.65 million		2	3		
80	1.8 million		5	6		

The success of UltraSolar is said to be based on the fact that they stand for quality and that people associate durability and sustainability with the brand's name. The manager believes that there is a clear positive trend for solar PV. The demand is rising and the government's 5.5$ per Watt peak subsidy for systems smaller than 50 Watt peaks[14] is bringing prices down, further stimulating the demand. Additionally, owing to the slow progress in the extension of the electricity grid and its current poor performance particularly in rural areas, the future for solar is said to be bright even in the long run. An astonishing 5% of UltraSolar clients are former, or as back up using, clients of the national utility UMEME. Because of frequent outages due to load shedding and unrealistic electricity bills, some disappointed households have decided to switch to solar PV.

In total there are three established solar businesses in the project area, all of which are located in Masaka main town. Each of these companies has at least 5 technicians serving the 19 sub-counties of the district, making an average of 15 technicians for the Masaka region. None of the focus sub counties has locally based solar companies.

None of the 7 SACCOs in the treatment area (sub counties of Kitanda, Bigasa and Butenga) offers solar loans. Considering that the solar companies are based in Masaka town, clients who purchase the systems on credit are able to access loans from

[14] Systems larger than 50 watt peak up to 500 Wp are subsidized with 4$/Wp. This subsidy is only given for systems that are sold through participating dealers or financial institutions.

institutions based in Masaka town although the installations are done at their residences in the villages within the district. In total, four institutions within Masaka and Kyotera towns offer loans for solar systems. Each of the institutions deals with a specific supplier, who is responsible for installations and maintenance. UltraSolar mainly works with FINCA MDI Ltd and to a lesser extent with Postbank under PVTMA, while other SACCOs work with solar companies not supported by GTZ. Whereas some SACCOs had problems of intermittent system supplies, the supply of systems by Ultratec was reported to be more regular and timely. The fact that FINCA and Postbank chose Nacosolar (today Ultrasolar) to supply them with solar systems is an indicator for the success of the support to Nacosolar. This is because they need the most reliable partners. In other words: GTZ seems to have laid the base for the functioning of PVTMA by creating a rural-based solar dealer that is able to participate in PVTMA. Before PVTMA became operational, Nacosolar worked also with UML Lyantonde (now Equity Bank), Victoria Basin MFI, Lwamaggwa MFI, South Buganda Teachers SACCO and Sembabule MFI. Some of these partnerships were established with support from GTZ.

7.4 The Solar Market in Rakai

Solar Energy Uganda's focus is Rakai District. In total, 467 Systems have been installed since project start (Feb 07- Feb 09) 317 of which have been installed in Rakai with the majority (around 250) having been installed in 2008. With a population of 31,409 households in its focus sub counties, the coverage for SEU is 1 system per 99 households for SEU SHS. Considering a market share of 70%, one can estimate that actual coverage is 30% higher which is 1 system for 76 households - an equivalent of 1.4% of all households.

Similar to Masaka district but in contrast to Bushenyi district, SEU estimates that there is still a significant market potential for solar systems in Rakai. For the year 2009, SEU expects to make 380 installations which would constitute an increase of roughly 50%. The current market share of SEU is estimated to be 70% while a 15% share each is held by Ultratec (supported by GTZ) and Solar Energy for Africa (not

GTZ supported). SEU, in contrast to the other GTZ supported companies only installs 2 different quality systems: a 10 and a 20 Watt peak system (see table for details).

Typical solar systems sold (Wp)	Sales price of complete system (UGX)	Profit margin	Current Monthly sales	Reported average monthly sales in the last one year	Systems sold in the last one year	Projected sales for 2009
10	327,000		35	20	250	380
20	650,000		20	5		

According to SEU managers, there is a slowly growing trend of new businesses trying to enter the solar market with the intention of making quick profits. However, given that they lack technical expertise in solar energy systems, they are likely not to be successful.

The two sub counties selected as the treatment region for this study (Kifamba and Kasasa) have two solar businesses (SEU and Dembe Enterprises) serving the region. Both companies have a total of 8 trained local technicians who conduct installations and routine maintenance. The control sub counties (Byakabanda and Dwaniro) on the other hand neither have locally based solar businesses nor solar technicians. None of the six financial institutions locally based in the treatment and control regions offers solar loan products. On a wider scale however, the district has 5 financial institutions (two banks and three SACCOs[15]) located in the main town (some of them with field offices in the villages) that offer solar loans. Similar to Masaka, the financial institutions serve clients from all sub counties in Rakai district, with an approximate average of 35 solar loans given per institution within the past year. Considering that SEU's business model is to offer credit facilities directly to its clients, the large sales and presence of technicians in the program access region could be explained by their access to financing options.

7.5 Solar Market Prospects

The different opinions on the market prospects for solar systems given by the local managers of the solar enterprises and notably the pessimistic previsions of Incafex in

[15] Equity Bank, Centenary Bank, Victoria Basin Microfinance SACCO, Lwamaggwa Twesitule SACCO and Kakuuto Microfinance SACCO.

contrast to the optimistic views of UltraSolar and SEU, seem to astonish at the first glance. But looking at the figures more closely one can see that Incafex - which estimates the quality solar market to show signs of saturation - has the highest sales prices. In contrast UltraSolar, which offers the smallest system for nearly half of the price, estimates that the prospects for quality solar systems are very good. However, it has to be noticed that the solar coverage per household is higher in the sub-counties in Bushenyi which were initially focused by Incafex (0.8%) than in Masaka (0.6%), where UltraSolar is operating. Thus the higher estimated demand in Masaka district can partly be explained by the lower coverage rate.

The lower coverage notwithstanding, the sales of Incafex are expected to decrease by 17%. In contrast UltraSolar – which offers cheaper systems - is expecting to double its sales in 2009. It is thus worth mentioning that the better prospects of UltraSolar might be due to the fact that their area of operation is larger than that of Incafex. Solar Energy Uganda - settled in the middle of the price range - expects growth figures of around 50% although the coverage of 1.4% is even higher than in the sub-counties served by Incafex. Here it is important to highlight the fact that SEU's strategy focuses on smaller systems to reach farmers and the lower social class which represents the large majority of the rural population. In contrast UltraSolar expects to increasingly sell larger systems targeting richer households. Nevertheless it is important to note that UltraSolar already took full advantage of the 5.5$ government subsidy (that is currently tested and will be rolled out during phase two of the ERT Program), decreased prices and their fully developed and well performing marketing strategy. In contrast Incafex and SEU, as they are not working with FINCA, PostBank or SACCOs that are registered at the Rural Electrification Agency to benefit from the subsidy, seem not to take advantage of the subsidy to decrease prices yet (which can in addition be seen as a proof of good management skills of the UltraSolar manager who is informed on new developments and is quickly responding to a changing environment). In addition Ultrasolar gets continuous and intensive support of her mother company Ultratec, which further explains the performance.

Despite the fact that price seems to be a major factor for the development of rural solar markets, the financing possibilities and conditions are often quoted to be even more important as the large majority of rural households can only afford a system on

a credit sale basis. In fact the financing possibilities seem to play a vital role. UltraSolar which has the highest development prospects is closely working with FINCA Uganda, a micro finance institution with a rural branch network and a solar loan product which is especially designed to integrate the 5.5 $/Wp subsidy. Conditions to open a savings account and to apply for a solar credit are very transparent, rapid and not bureaucratic. The procedure is institutionalized and only a formal question of collateral needs to be proven. Despite some start-up difficulties, the cooperation is said to work without any delays now. Within one month after installation the system is inspected, the 5.5$/Wp subsidy credited to the financing institution and UltraSolar is paid. The inspection is not necessarily done by the government which makes them an attractive partner to solar companies due to their efficiency. Further, UltraSolar's main business strategy is based on the cooperation with Savings and Credit Cooperatives (SACCOS) that are cooperating with Postbank and hence also indirectly aggregated to benefit from the 5.5 $/Wp subsidy. These SACCOs - because of their standing and the trust the local population have in them - are very efficient in mobilizing the demand for solar systems and in organizing and enforcing payment. The whole distribution system is working in a very efficient way as responsibilities are well defined so that players concentrate on the activity of their comparative advantage. But these results can only be achieved after a lot of support to establish this relationship. Often the contrary is the case and partnerships between companies and SACCOs are not that successful depending on the context.

SEU uses a similar but more centralized mobilization and financing structure. Having created their own internal "solar bank", SEU offers its own solar loans. In consequence, bureaucracy is reduced and transactions are facilitated. Similar to the UltraSolar's cooperation with SACCOS, SEU creates "cells" – groups of households interested in purchasing a solar system, each group comprising of a mobiliser, an accountant and a technician. These cells function as mobilizers and money collecting associations. This system is reported to trigger the demand and supply for solar systems in a sustainable and efficient way.

Although Incafex is also working with micro finance institutions and SACCOs, the cooperation is found to be on a less institutionalized basis. The local agent of Incafex is the technician, the promoter and link to the finance institution in one person. In

contrast to the other companies, Incafex has no physical local branches as solar systems are sent on the bus and installed by Incafex's agents. This kind of informal distribution system based on ad hoc arrangements - although working - seems to be less efficient as players tasks are less formalized and not focusing on their main field of activity – which leads to efficiency losses and might further explain the lower performance. These factors – in addition to the price - seem as well to be responsible for the better business prospects of UltraSolar and SEU than for Incafex.

7.6 Solar Market Employment Effects and "Green Jobs"

Following two years since project start, all the three supported solar companies have opened rural branches in the three main districts of Masaka, Bushenyi and Rakai. Incafex - in contrast to SEU and UltraSolar - has not built up an equivalent large physical solar structure but only one small shop in Ishaka. Accordingly in the case of Incafex, apart from the 8 technicians/agents who cover all sales, promotion and installation tasks, there is no additional employment created in the management or sales sector.

UltraSolar on the other hand opened one local shop and office in Masaka employing one manager, one secretary, one full time sales person and six technicians who carry out the installations. Further, "satellites" are created with agents in Lwamaggwa (Rakai district) and Mateete (District Sembabule). The total number of employees in Masaka district is nine. In Rakai district, SEU opened eight shops and employs 15 people in total including one manager, seven mobilizers and seven technicians.

Apart from the direct employment in the solar sales and installation business, there are additional indirect employments that were created, not directly because of the GTZ program but generally and notably in the banking sector. FINCA, a microfinance institution, has one Loans Officer employed specifically to handle solar loans in Masaka. In contrast, the SACCOs offer solar loans as one of their various loan products and use the existing Loans Officers to manage the solar loan portfolio alongside other loan products.

In order to quantify the net employment effect of GTZ's activities to promote rural solar markets, one should identify which jobs are newly created, which are transformed and which are lost. As SHS using households continue to use nearly the same amount of traditional energy sources including kerosene, the demand for installation and service for SHSs is not crowding out other energy sectors but is additional. Further, the solar business is tapping into a new non existing market that is not competing with other off grid energy solutions such as generators (because of their high running costs). Accordingly it can be concluded that no jobs are lost.

Most of the technicians had previous formation like electricians and were additionally trained in solar PV. The same accounts for the salesmen, -women, secretaries and loan officers who work in solar shops, offices or banks but who just specialized in solar. Accordingly, those jobs are transformed. Up to now there is no full apprenticeship in the solar sector so one might not consider these jobs as entirely new. Nevertheless, as the solar business is tapping a completely new market, most of the people now involved in the solar business are likely to be replaced in the former sectors in which the personnel was employed beforehand.

As a result, it can be concluded that most of the solar jobs created are additional, which in consequence increases the total number of the working population. Accordingly, the total net employment effect after two years enhanced development of rural solar markets in the three districts (an achieved coverage rate of roughly 1% out of 65,000 households) can thus be roughly estimated at 33 newly created jobs in the solar business including the banking sector. Although economies of scale might reduce the net employment effect, one might calculate with a rough rule of thumb that a 1% increase in solar coverage leads to an increase of 0.02% new direct employments in the solar business. Most of the created solar jobs are likely to be solar technicians (over 90%) whereas some few solar related jobs are found in the management, sales and financing sector.

In addition to these direct jobs in the solar business, new businesses that purchase a SHS to use it in a productive way and that tap into a new un-served market create further indirect jobs. After two years, these new businesses, notably phone charging

and electric hair cutting which are all run by one man or woman, are still rare and estimated to be not more than five in total (0.004% new indirect jobs).

Concerning the quality of the jobs, they can be judged decent as working conditions and payment are said to be good although most of the contracts are not guaranteeing any social security and not always full time jobs as they depend on the demand. Qualifying the type of jobs, they can be all classified as “green jobs” as they are all related to and sustaining a green, low-carbon economy. Nevertheless the jobs have different “shades of green” related to the environmental foot print of the job. Accordingly, while the solar technician might be settled at the top of the green jobs scale the secretary, salesmen and -women as well as the solar loans officer and manager together with the indirectly created jobs in classic businesses - although working in the green economy - might be settled at the bottom of the green jobs scale. In contrast to the solar technicians, their formation is less specific with less solar qualifications which make them easily substitutable.

8.0 CONCLUSION AND RECOMMENDATIONS

The need for a tripartite market structure for sustainable rural solar markets

It is concluded that the supply structure of a sustainable rural solar market needs to be composed of three main elements to be sustainable, hereafter named as the tripartite rural solar market structure. This structure consists of (i) the mobilizing part which is substantial to raise awareness and the demand for solar systems through promotion, marketing and information, (ii) the financing part with a solar loan that is necessary to enable rural households to access loans and (iii) the technical element, the solar company itself which apart from providing the equipment, the design, the technical installation and the after sales service is also coordinating and managing the tripartite structure.

The tripartite structure of actors engaged in mobilization, financing and installation and the specialization of and efficient cooperation between these actors is found to be central to the development of rural markets for solar PV.

Best practice - factors that determine the success to develop a rural solar market

In summary, one can conclude that because of the less cooperating and less specialized tripartite structure of the solar market and the better performance of its elements - which in particular means lower prices, better demand mobilization and more efficient financing institutions - the rural solar development prospects seem to be better for UltraSolar and SEU than for Incafex.

In addition, further pre-conditions were found to be necessary to successfully build up a rural solar business. Conditions include quality products or at least transparent pricing for lower quality and the availability of upgradeable solar products. Hence, the consumer needs to be able to make his own decision and should not be restricted to only one-size-fits-all systems that are offered with the option to take or to leave it. In addition, local professional advice, design, installation, after sales service and trouble shooting is fundamental to the development of rural solar markets. These services need to be locally available. Thus, a local infrastructure of solar enterprises and technicians is necessary. Concerning these fundamentals, all three companies (UltraSolar, Incafex and SEU, although Incafex has a less pronounced local structure

than UltraSolar and SEU) have built local capacities with the help of GTZ and international donors.

To sum it up, these pre-conditions are more or less equally addressed by the three GTZ supported companies. Accordingly the differences in the performance and prospects can be attributed mainly to the degree of specialization and coordination of the tripartite supply structure and the performance of its elements which are notably the price (which is a function of the technical and management performance of the installing institution and external factors such as subsidies), the demand mobilization capacity and the provision of solar loans.

In general one can conclude that three main factors and their interaction determine the success of the creation of a sustainable rural solar market:

- The price
- The mobilization of demand
- The financing options

Whereas successful solar businesses have to fulfill basic pre-conditions which include:

- Local professional sales and service infrastructure (local enterprises and technicians with physical sales and service structure in form of a shop)
- Local capacity in advice, demonstration, design, installation and service
- A variety of solar products that can be adapted to different needs
- Quality products or at least transparent information and prices for low quality

Best practice was found to be a specialized tripartite solar supply structure with professional mobilization, financing and supply (installing) institutions with clear duties and responsibilities with an underlying professional local sales and service infrastructure.

Impact of the GTZ Support for the development of the rural market

According to two of the local managers (SEU and UltraSolar) the support was essential and even a pre-condition to develop the solar business in rural areas. According to Incafex the support was very helpful and facilitating but not a pre-

condition to develop their rural solar market. However, these statements have to be interpreted with caution as strategic response behavior might have influenced the answers. Nevertheless, it is worth mentioning that all of the three companies said that today their rural solar business is profitable and sustainable even without external support. Noting that the companies are planning to expand their business with internal resources coming from own profits, one can conclude that a sustainable rural solar market is emerging.

Looking at the facts it can be seen that past as well as forecasted installations are much higher in the region that was supported by international donors than in the control region where no support was given. Further, also the total number of active solar companies and solar technicians is higher in the treatment than in the control region. So it can be said that the local sales and service infrastructure for solar products is denser and more widespread because of international support. As a rule of thumb an increase of 1% in local solar coverage increases the direct employments in the green economy by 0.02% in the respective area.

Notwithstanding the fact that all three rural solar businesses are said to be sustainable and profitable without any external support, none of them are satisfied with the profits. They would like to raise prices but fear that it might harm the solar market because of the low purchasing power of the target population. This underlines the fact that rural business has high upfront as well as high running costs that only in the capital (Kampala) based companies might not be willing to incur. As a result, in order to catalyze rural solar markets it is vital to support local enterprises and build up local infrastructure.

In order to enter the rural solar market it can be concluded that the international support is essential and sometimes even a pre-condition for the development of rural solar markets. A well developed and well cooperating tripartite solar supply structure of mobilization, financing and supply (installation) is found to be conductive for the development of rural solar markets.

In order to increase the impact of international and GTZ market support - notably to foster the take up rate - it is recommended to adapt a “social market approach” which

targets farmers and micro enterprises - the “bottom of the pyramid” - and smaller systems. In order to reach the poor, out of the three supported solar companies, SEU is pursuing the most promising strategy. The ‘social market approach’ should comprise complementary awareness and training services provided by the solar companies to increase the awareness and take up of the mass population. It should be further aimed to bring down energy expenditures of SHS users and to foster the productive use of solar PV.