Characteristics and uses of Solar Home Systems in Selected Uzn-Electrified Rural Villages in Muleba District, Tanzania

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Abstract: *The use of solar electricity in un-electrified remote villages is widely recommended as a more viable alternative to grid electricity in these areas. However, despite a large body of literature on the impacts of solar electricity in remote areas, the use of solar electricity in un-electrified rural villages in Tanzania has not been in practice as much as it should have been due to lack of qualified solar electrical technicians which in turns results into Solar Home Systems (SHSs) failure. Technical failures often lead to high cost for users, disappointment with the solar electricity technology and a strong negative altitude about solar electricity technology. Preventing avoidable technical problems is therefore one of the main driving forces behind activities to enhance widespread and quality solar electricity in un-electrified rural areas. This paper investigated the status of all SHSs in Karambi, Kasharunga and Kyebitembe wards (Muleba district), their uses as well as system performance, limitations and problems. Results indicate that about 88% of all SHSs were performing as expected and households were happy with their systems.*

Key words: Un-electrified remote village, solar home system, solar electricity, Photovoltaic, households

INTRODUCTION

Modern societies strongly depend on reliable, affordable and sustainable electricity supplies for their development. Definitely, electricity is an obligatory input in the process of economic, social and industrial development of any society. Indeed, the availability of electricity is directly related to the living standard of any community (Kivaisi, 1999). Despite of this fact, many people in Tanzania have no electricity as only about 10% and 2% of the population in the urban and rural areas, respectively, are connected to grid electricity (TNBS, 2000). It has also been reported that extending grid electricity to many rural villages in Tanzania would not be economically viable in the near future and in some villages not practically possible due to low capital returns and sparsely population (Mwhihava and Mbise, 2003). There are little prospects that financial resources will become available and economic viability will encourage the national electric utility (Tanzania Electric Supply Company Limited, TANESCO), to undertake electrification of the remote rural areas in the foreseeable future. In fact, it has been reported that the privatisation of TANESCO had slowed down the expansion of electricity distribution in rural areas as the decisions of the investors are normally made based on the return on capital rather than on political considerations (AFRODAD, 2007). This suggests that 98% of the rural communities in Tanzania will continue to live without grid electricity for several decades; a situation that not only deteriorates the development process but also hinders poverty alleviation.

Therefore, the only possibility of getting electricity in un-electrified rural areas in Tanzania is through the use of Solar Home System (SHS). A SHS is a small autonomous energy station, powered by a Photovoltaic (PV) module, that provides electricity for basic services such as lighting, radio, television and operation of small appliances in rural households found in sparsely populated areas and far away from the electricity grid (Scheutzlich et al., 2001; Diessen, 2008). The system consists of a PV module which converts the solar radiation into electricity; rechargeable battery which stores the generated energy for use in the night and during cloudy days; charge controller which controls the charging of the battery; low consuming appliances (light bulbs, radio and TV), switches, interconnecting wires and PV mounting rack (Roberts, 1991). It may also include an alternative current (AC) inverter, circuit breaker (to prevent the cabling from overloading) or a generator as a backup energy source (Roberts, 1991; Foster et al., 2010). A typical SHS for rural applications is shown in Figure 1 (TASEA, 2005).

Depending on income levels, technical and components availability, most of the SHSs found in the rural areas can be grouped into four categories as follows (Diessen, 2008):

- Small SHSs $(\leq 20\ \text{Wp})$ for lighting and radio only,

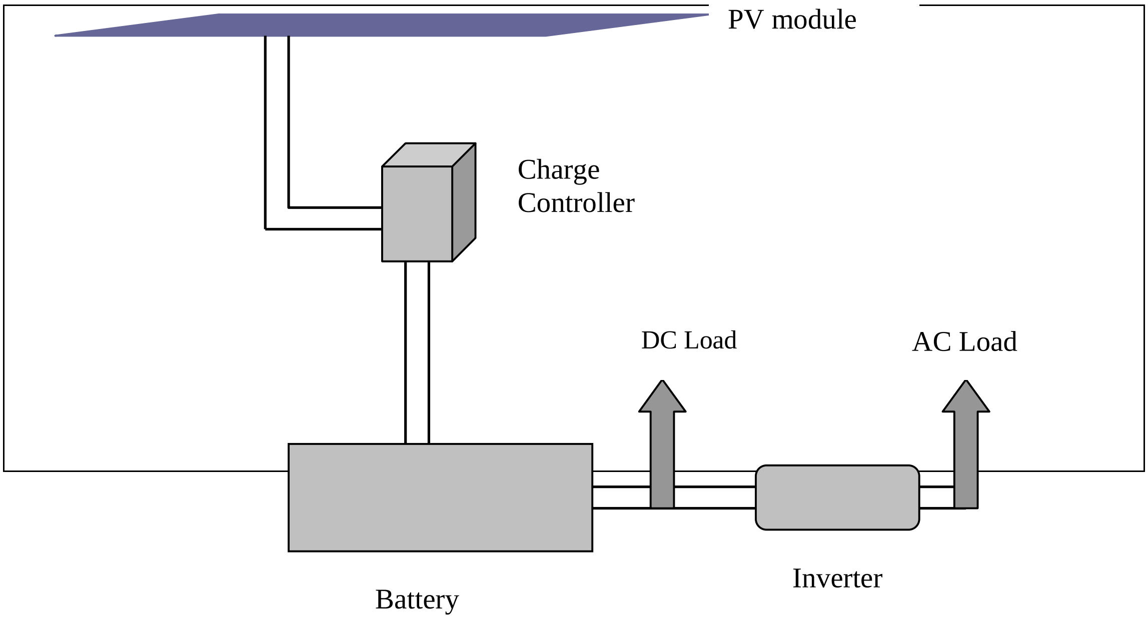

Figure 1: The basic SHS components for rural households (TASEA, 2005). Note: DC means direct current which is unidirectional flow of electric charge from the PV module.

- Medium sized SHSs $(20-50\ \text{Wp})$ for the basic energy needs like lighting the house, radio and a black and white TV,
- Large SHSs (double the size of the medium system) for lighting a large house, radio and coloured TV,
- Extra large SHSs (the same as large SHS) but in this case any electrical appliance can be connected. This is perceived as more luxurious as it resembles grid electricity.

Solar electricity to un-electrified remote villages has significant impact on the standard of living of rural communities. Some of the benefits associated with solar electricity in rural areas are summarized in Figure 2.

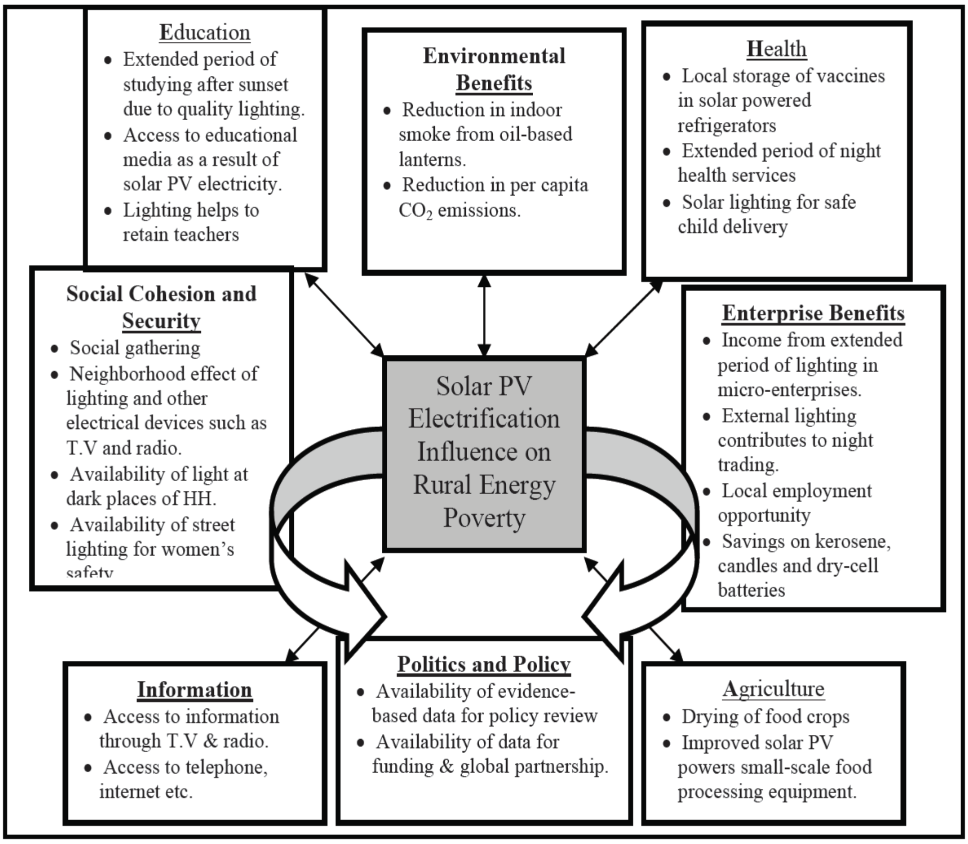

Figure 2: Multi-sectoral linkages of PV electricity influence on quality of life in off-grid rural communities (Obeng and Evers, 2009).

Despite of these advantages, solar electricity in un-electrified rural villages has not been in use as much as it should have been due to high initial cost and lack of qualified solar technicians (Derrick, 2000; Kassenga, 2008). However, taking into consideration of the energy expenditures for lighting and entertainments only, it can be seen that affordability is not the main problem in most rural areas in Tanzania (Paul, 2010). The main barrier to widespread of solar electricity technology in most rural areas in developing countries is embedded in attitudes toward solar electricity (Derrick, 2000; Söker, 2007). The arguments such as 'it does not work', 'the technology is too complicated', 'it is not appropriate', 'I don't know about the technology' etc, are militate against the use of solar electricity. This lack of acceptability is attributed to a great extent to poor system reliability which is due lack of qualified solar technicians, particularly in remote areas (Van der Plas and Hankins, 1998; Mulugetta et al., 2000; Gustavsson, 2004; Nieuwenhout et al., 2004). Technical failures often lead to high cost for users, disappointment with the solar electricity and to negative altitude about solar electricity technology. Preventing avoidable technical problems is therefore one of the main driving forces behind activities to enhance widespread and quality solar electricity in un-electrified rural areas.

This paper investigated the status of all SHSs in Karambi, Kasharunga and Kyebitembe wards, their uses as well as system performance, limitations and problems. It was anticipated that there was a need to obtain technical insight on the status of the installed SHSs on the surveyed wards as this will add valuable information on the improvement of the system's reliability. The improved reliability would simulate households withnot SHS to confidently invest in solar electricity technology and hence improvement in their living standard.

GEOGRAPHICAL LOCATION AND ENERGY SOURCES IN THE SURVEYED WARDS

Figure 3 is a map illustrating the geographical location of the surveyed area. Karambi, Kasharunga and Kyebitembe are among the 31 wards of Muleba district in Kagera region, North-western corner of Tanzania (Kagera region report, 2003). As shown in Figure 3, Muleba district borders in Bukoba Urban the north by and Bukoba Rural districts, Biharamulo district, to the south and to the east by Lake Victoria. To the west is Karagwe district. In 2002, the district had a population of 386,328, of which about 12% were from the surveyed wards (TNBS, 2002). Geographically, Muleba is the remotest district from the administrative headquarters (Dar es Salaam).

The households in Karambi, Kasharunga and Kyebitembe wards use many different sources of energy for their lighting and entertainments energy requirements. These include kerosene, diesel, candles, wood sticks lead-acid batteries and dry batteries. The choice of a particular energy source depends strongly on the income level of the household. While the other wards such as Kishanda, Nshamba and Muleba Urban are served with national grid electricity generated from Uganda, Karambi, Kasharunga and Kyebitembe wards had no electricity (United Republic of Tanzania Parliament Records, 2007). The only hope for people in these wards to enjoy the ‘fruits’ of electricity is through SHSs.

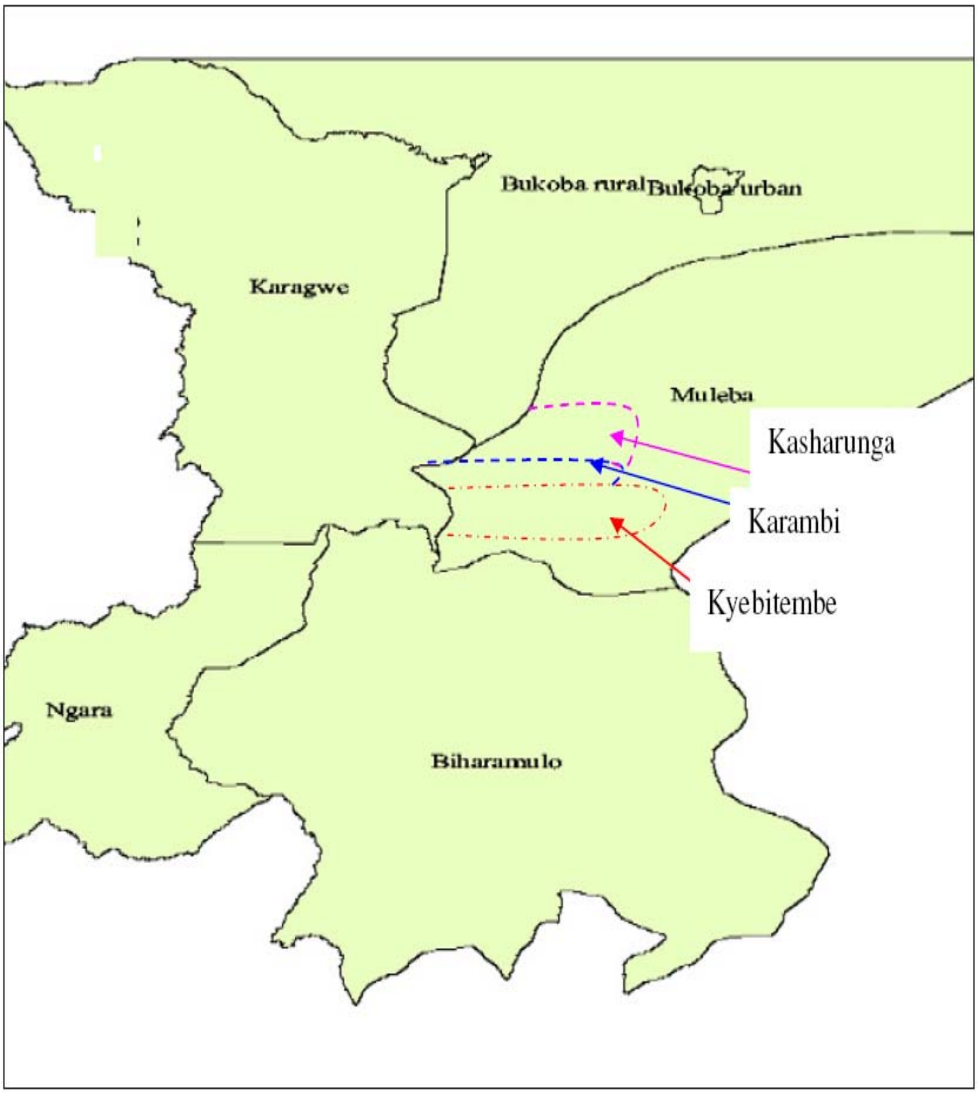

Figure 3: Map of Muleba district (Kagera region) showing the study wards (Kagera region report, 2003).

METHODOLOGY

Sample Population

As indicated in Figure 3, this study was conducted in three wards: Karambi, Kasharunga and Kyebitembe, targeting all households with solar electricity. In order to establish if there was any relationship between owning a SHS and income or education level, neighbours to the SHSs respondents were also included in the survey. The households with a SHS were identified using three different methods: One was through a directive from the ward executive officer who knew the house with solar electricity (25%). The second was through SHS owners or local informers who knew of the systems nearby (62.5%). The third was location of systems at random by sighting them – a house with a TV antenna in un-electrified village had a high probability of having a SHS (12.5%). The last two methods are basically random, although the latter favoured the locations close to the road and densely populated village centres.

Primary Data Collection
To collect the required information efficiently from the target groups, a 25 item questionnaire consisting of four sections relating to the research objectives was developed. Instructions were given to each section and questions of the questionnaire. A pilot study was carried out in order to assess the problems and ambiguities with the questions, items and the general layout of the questionnaire. The participants in the pilot study (whose characteristics were similar to the study sample) reported a few minor difficulties that resulted in minor alterations before the final draft of the questionnaire was completed. The questionnaire included closed questions, open-ended comment questions and ranking typee questions.

In addition to questionnaire method, an interview was conducted with selected respondents to obtain further information on the research objectives. Three different questionnaires, each consisting of three sections, were used for each group. While the basic structure and some few questions of each questionnaire was the same, special questions were asked for each group which was not relevant to the other group. A pilot study was also carried out on the interview pre-structure questions and there was no difficulty observed.

Secondary Data Collection
In addition to the study findings, relevant reports from various PV stakeholders, publications and internet search were used to provide secondary data.

Procedure
A total of 112 questionnaire packages were distributed to all the targeted groups. Of which 16 and 96 were distributed to the households with and without SHSs, respectively. Each questionnaire package was accompanied by a letter explaining the general aims of the study and the respondent was asked to return a questionnaire with all questions full completed. Table 1 shows the number of returned questionnaires by wards and sex.

Ward	**Households with SHSs**			**Households without SHSs**		
	Male respondents	**Female respondents**	**Total**	**Male respondents**	**Female respondents**	**Total**
Karambi	7 (43.7)	2 (12.5)	9 (56.2)	44 (51.2)	10 (11.6)	54 (62.8)
Kasharunga	3 (18.8)	0 (0.0)	3 (18.8)	12 (14.0)	2 (2.3)	14 (16.3)
Kyebitembe	4 (25.0)	0 (0.0)	4 (25.0)	15 (17.4)	3 (3.5)	18 (20.9)
Total	14 (87.5)	2 (12.5)	16 (100)	71 (82.6)	15 (17.4)	86 (100)

Table 1: The number of surveyed respondents by wards and sex. Note that figures in parentheses show the percentage of respondents with respect to the total respondents in each group.

In addition to the questionnaires, all households with SHSs and three households without SHSs from each ward were interviewed. A pre-structured questionnaire was used for the interviews. During the interview visit to the households with SHSs, the author also examined the physical appearance of the SHSs, structure mounting, mounting place, direction, electrical wiring and the general status of the SHS.

Data Analysis
At the component level, the status of a well-designed SHS was quantified by determining if all the necessary components are available and each component was working as expected from the

theory. Besides this status indicator, another characteristic indicator that was used to quantify the system was the size and type of the PV module. The size of the PV module provides the information on electrical energy expected from the system while the type of the PV module indicates the overall performance efficiency of the PV module. Furthermore, atitude towards solar electricity from households with SHSs was used to assess acceptability of the solar electricity technology in the surveyed wards. This was done by asking the respondents to indicate whether they were satisfied with their solar system or not. This type of question, however, is notoriously difficult to interpret, because in some cultures it is not common to forgive open criticism. Therefore, an indirect question that linked with the household's satisfaction was added to the questionnaire. For example, households with solar electricity were asked to indicate if they would recommend the solar electricity technology to others.

RESULTS AND DISCUSSIONS

Status of Households with and without Solar Home Systems

Since the level of income and education influence the ability and desire to acquire new technologies (Ali, 2002), one of the specific objectives was to investigate the differences in income and education levels between households with and without SHSs. As the level of income was extremely difficulty to determine due to multiple income sources and many people obtaining erratically/seasonally (depending on the time of the year), the difference between the two groups was examined using income sources such as paid employment (teachers, soldiers, civil services, medical doctors, laboratory technicians, pastors, etc), farming and business activities. As shown in Figure 4, most of the SHS owners had both paid employment (38%) and farming activities (56%). In addition, some of the SHS owners were businessmen (25%). In the business group, each person had different business activities such as hotels, bars, shops, music halls, car transports or selling agricultural products (coffee, maize, beans or cassava). On the other hand, most non-SHS owners were both small scale farmers (90%) and had paid employment (30.3%). Only 6.7% of respondents without SHSs indicated that they had business activities. It can also be noted from Figure 4 that, like most rural areas in developing countries, other activities (22.5%) such as day labour, home-based activities and fishing form a significant part of the income generation for unemployed households.

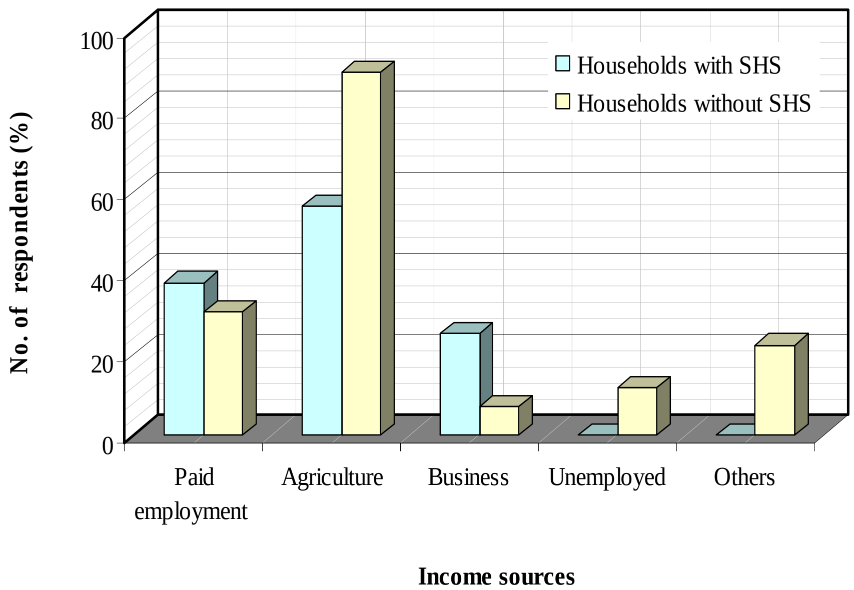

Figure 4: Comparison of income sources for households with and without solar home systems.

The households that owned SHSs generally had higher educational levels compared with those without SHSs as shown in Figure 5. In households that owned SHS, all the heads of the households had education level between primary/middle school and university degree. However, the majority of people in this group had either secondary certificate, diploma (43.8%) or university degree (31.3%). Only 25% of the heads of the households had primary school education. On the other hand, none of the households without SHS had university degree and the majority (61.6%) had primary school education. Only 32.6% had secondary school education. As illustrated in Figure 5, about 6% of the heads of the households without SHSs indicated that they never attended formal education although 60% were able to read and write. It was learnt that those who could read and write attended Adult Education commonly know as *Kisomo cha Elimu ya Watu Wazima*. This informal education was introduced in Tanzania by Mwalimu Nyerere in the late-1960s to wipe out illiteracy (Mbunda, 1972).

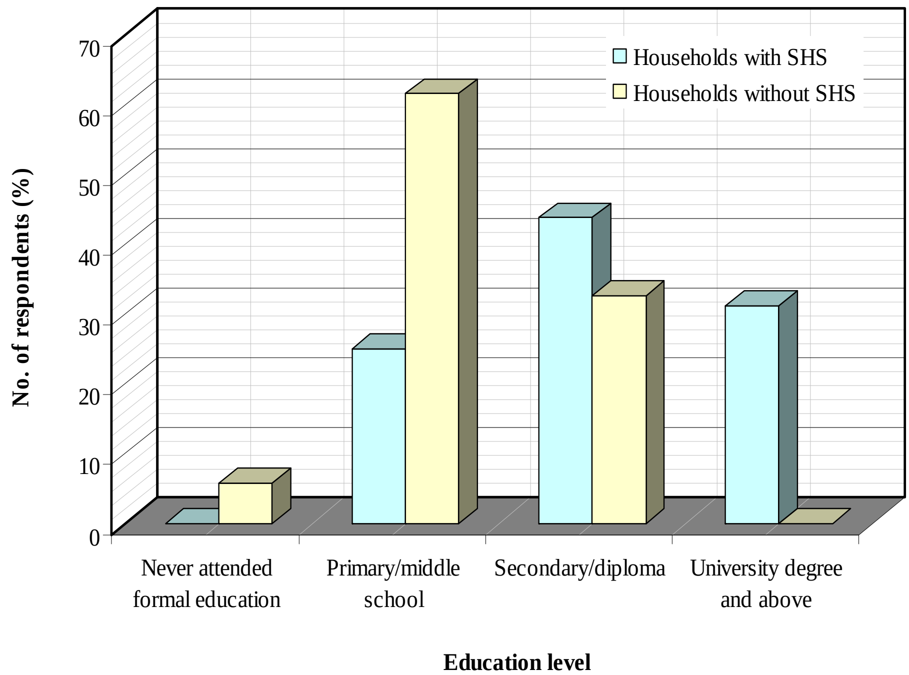

Figure 5: Comparison of education level for heads of households with and without SHSs.

From this result it can be concluded that early adaptors of solar electricity in these wards fall into households with higher incomes and higher education levels. A similar result has been reported by Ali (2002) who found that income and education level influenced significantly the purchasing ability of SHSs in rural villages in Bangladesh.

Characteristics of Solar Home System Components in the Study Wards

The PV Module

All the households and institutional that owned SHSs had only one system and these systems were purchased with cash as credit is not available in these wards. As illustrated in Figure 6, most of the owners reported that they purchased a particular type and size of the PV module due to availability and cheaper price (75%) whilst about 6% said it was due to module reputations. None indicated that it was due to the load demands of their energy requirements. Only 19% said they didn't know the reason as they were not there during purchasing stage. These were the respondents from SHSs owned by institutional.

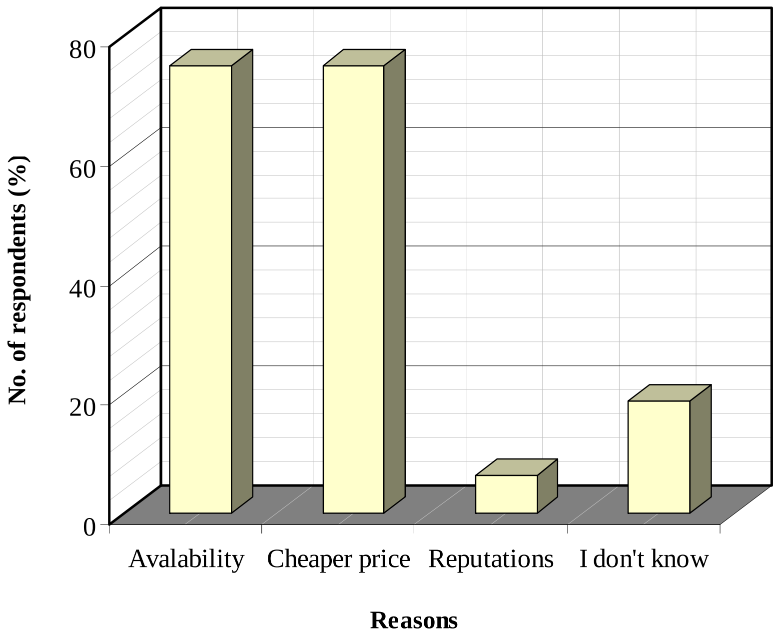

Figure 6: Reasons for SHS owners to purchase the size and types of PV modules.

Figure 7 shows the size of the PV module purchased by each household. As expected, the typical size of the PV module owned by the rural households tends to be small, ranging from ≤ 20 W to 70 W. As shown in Figure 7, 25% of the SHS owners reported that they owned 20 W PV modules while those who owned 50 W and 70 W were about 31% and 19%, respectively. On the other hand, about 13% reported that they didn't know the size of their PV module while the sizes of the PV owned by institutions (13%) were more than 100 W. This finding is consistent with other recent similar study on size and ownership patterns (Voravate et al., 2000). Most of the PV modules (88%) consisted of amorphous silicon whilst the rest were mono-crystalline silicon. The reason for higher amorphous silicon PV modules was probably due to its lower cost and product availability. The other reason could be due to small power demand for the village households (amorphous PV modules have lower conversion efficiency compared to the other types of modules such as crystalline or mono-crystalline).

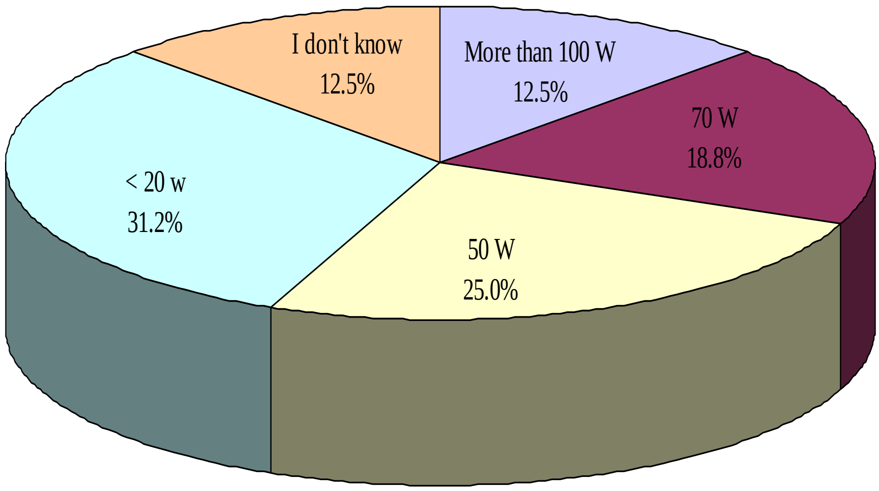

Figure 7: Size of the PV module owned by the households and institutional.

The major factor limiting the performance of amorphous silicon PV modules is the light-induced degradation since most modules degrade about 12–20% before reaching a steady state (Markvart and Luis, 2005). Although some PV company such as Zara Solar Ltd claimed to be purchasing the amorphous silicon modules only from reputable manufacturers who offer a warranty on their products (Parpia, 2007), there is still a problem in Tanzania with many small electrical shops offering cheap, low quality amorphous silicon modules which look exactly like the well known brands. These types of PV module tend to fail after a short time and jeopardize the acceptability of solar electricity technology in rural areas.

Charge Controller

Figure 8 illustrates some of the major components found in the SHS (except the PV module, appliances and connection wires). It can be seen that about 19% of the SHSs did not have charge controller, a situation which can cause deep discharge and overcharging. While the risk of overcharge is relatively small with small PV modules, the major concern seem to be the deep discharge of the batteries because lack of charge controller leads to battery deep cycling due to sulfation. The problem of overcharging was not expected to happen since the matching of the PV module to battery in virtually all cases was poor, with seriously undersized modules.

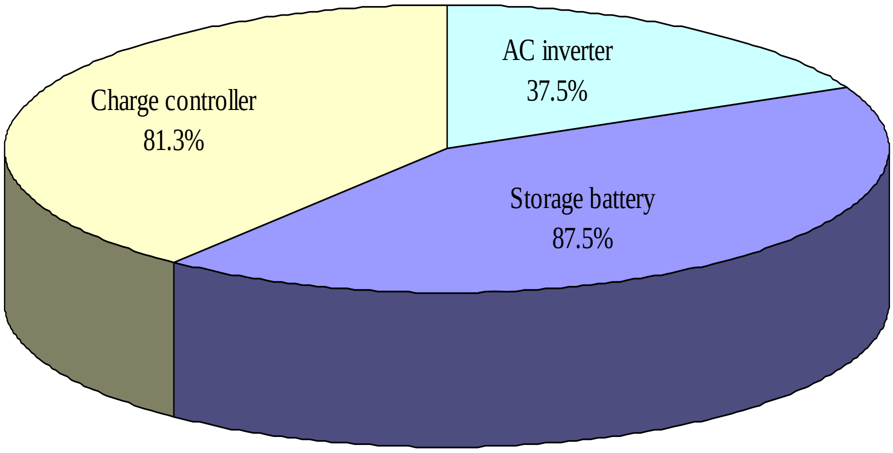

Figure 8: Number of SHSs with storage battery, charge controller and DC/AC inverter.

Storage Battery

The majority of the SHSs (87.5%) had storage battery as shown in Figure 8 and those without energy storage (12.5%) were mainly used during the day time when sunshine was available. It was found that these types of SHSs were mainly used for mobile phone charging and entertainment activities (radio-cassette). On a SHS lifetime basis, storage batteries constitute the highest contribution to the life-cycle cost. Most of the serious problems with SHSs are battery related and sometimes depends on the quality of the battery. However, the quality of the battery is difficult to assess from the outside. User behaviour is as important to the lifetime as the initial product quality. In the surveyed SHSs, it was observed that 75% of the batteries had open circuit voltages. This suggests that users drained their batteries as much as they could while hardly allow the battery to be fully charged.

In one of the households, the owner reported that he had purchased the PV module about three years ago and the first storage battery was deep cycle battery. It was learnt that when the battery expired it was replaced by automotive battery. If the charge controller is not re-set to match the charge/discharge characteristics of a new battery, replacing dissimilar battery may result into deep discharge, reducing the battery service lifetime.

DC/AC Inverter

While the uses of battery storages and charge controllers were common among the surveyed SHSs, the use of DC/AC inverters was limited to few households. As shown in Figure 8, about 38% of the respondents in the three wards indicated that their system had an AC inverter. Limited use of inverters may be associated with the type of electrical appliances used in rural areas, its cost as well as lack of qualified solar technicians.

PV Module Installation

About 69% of all the surveyed SHSs had pole mounted modules (Figure 10) while 19% were mounted on houseroofs as shown in Figure 9. Both house-roof and pole mountings do not allow changes in module orientation once fitted. It was also observed that about 13% practiced ‘basking’ their loose modules in the sun during the day and taking them indoors at night. Basking was predominantly practiced with low cost systems not procured with mounting hardware. In these cases it is unlikely that both orientation and tilt could be regularly optimised and at ground level the risk of shading and dust would be obstacles to efficient energy capture by the modules. The risk of breakage is also high due to the accessible position of the modules and the daily indoor/outdoor movement. However, the risk of being stolen was miminmized.

Figure 9: Roof-house PV module mounting.

Error in installation was also observed in one PV module, as shown in Figure 10, where part of the PV module was shaded during the day. PV module shading leads to incomplete battery charging and sulfation of the battery plates which results into pre-mature battery failure (Lynch, 2006). In additional, the use of too small wire sections, inappropriate fixing of wires on the walls, lack of connection boxes and twisting of wires instead of using switches were also found in about 19% of the surveyed SHSs. Low quality of installation leads to unnecessary losses in system functionality.

Figure 10: Wrong installation place of the PV module

Types of Lighting Lamps

Most of the SHS owners reported that they used compact spiral fluorescent lamps (56%) while those who used tubular fluorescent lamps and incandescent light bulbs were about 19% and 25%, respectively. Utilizing tubular fluorescent lamps in SHS provides substantially higher lighting levels than would be possible with either compact spiral or incandescent light bulbs. Spiral fluorescent lamp has slightly reduced efficiency compared to tubular due to the excessively thick layer of phosphor on the lower side of the twist (Roberts, 1991). The higher number of households using compact spiral fluorescent lamps was probably due to its cheaper price and availability.

Other Observations

Unusual SHS

One household was found to have a second hand PV module for light and entertainment purposes, which the owner claimed he purchased from someone (in town) who stopped using it after acquiring grid electricity. From its appearance, the module was of a poor quality and had no charge controller, thus the frequency with which the battery must be replaced and therefore the cost of the SHS is increased. The discoloration in the module and the corroded wires were the evidence of degradation. The SHS had an automotive battery which was inappropriate. The module was installed on an eastward-facing roof slope rather than facing the south as recommended (Roberts, 1991). The module was mounted directly on the metal roof rather than on a mounting structure that would allow air circulation to cool the PV module and improve its performance. The system was installed without basic safety considerations such as electrical grounding or a compartment to protect family members from accidents with the battery. The owner reported that the system could only light two bulbs and a small radio cassette. This system certainly failed to meet the norms and standards expected of a well designed quality SHS. This unique system illustrates, on one hand the importance of electricity in rural areas, and on the other hand the importance of local solar technicians in successful implementation of PV electricity in rural communities.

Thieves of PV Modules
One household reported that previously his PV module was stolen. When he purchased the replacement, he used antitheft nuts. Another owner said he normally patrols the PV module during night while two households used 'basking' their modules. All these methods, however, are not permanent solutions to this problem. Alarms to the PV module could be a best solution, but this will add cost to the system. The problem could be completely eliminated if all the households had SHSs or the wards are electrified by grid electricity.

Solar Electricity Uses and Benefits
Solar Electricity Uses
As solar electricity has many applications as illustrated in Figure 2, the study intended to find out the main uses of the solar electricity in the surveyed wards. To assist in understanding this, the questionnaire included a question asking the household to indicate the uses of their SHSs. The question had four options: for home uses only, for home and business uses, used in business premises only and used for social services (school, dispensary, churches and telecommunication centers). As illustrated in Figure 11, the majority of the SHSs (68%) were purchased for home purposes only whilst 19% were used in social services (dispensary: 6.3%, churches: 6.3% and telecommunication center: 6.3%). Only 13% reported that their SHSs were used for both business and home activities whilst none of the SHS was used for business only. The reason for none existence of SHSs that were used for business activity only was probably due to the fact that all business activities (such as mobile phone charging, light and entertainment in business premises) took place in houses where the owners lived. In these wards, the households using SHSs for business purposes had no separate houses for business activities.

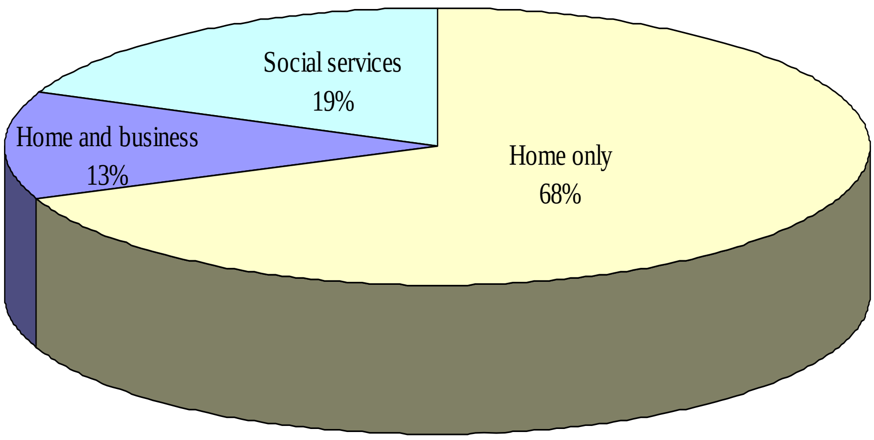

Figure 11: Uses of solar home systems in the surveyed wards

Benefit of Solar Electricity

All households with the SHS were asked to rank the perceived benefits of their SHS from a list of possible benefits. The list included:

- Increased quality of life due to improved light,
- Increased study hours, specifically for students,
- Increased access to entertainments and information (radio, TV and mobile phone),
- Increased working hours after dark,
- Increased income generation like mobile phone charging and barber shops,
- Reduced workload for women and children due to reducing needs for cleaning kerosene lamps and lighting wood sticks collections,
- Increased working and walking flexibility in house after dark, and
- Increased security in the homestead during night.

As shown Fn figure 12, all households considered solar electricity as having resulted in improvements in their quality of life (due to improved light) and reduction of workload for women and children (due to fewer hours spent in collecting wood-statics for lighting). About 94% of the households also strongly agree that solar electricity increased their access to entertainments (through radio-cassette, and TV football and other sporting programs) and information (through mobile phone, radio and TV). However, majority of the respondents (75%) disagreed with the statement that solar electricity increased their income generation. Although PV electricity was not directly used for productive purposes, the author strongly believes that it definitely served to boost business in shops, bars, restaurants, motels and mobile phone charging.

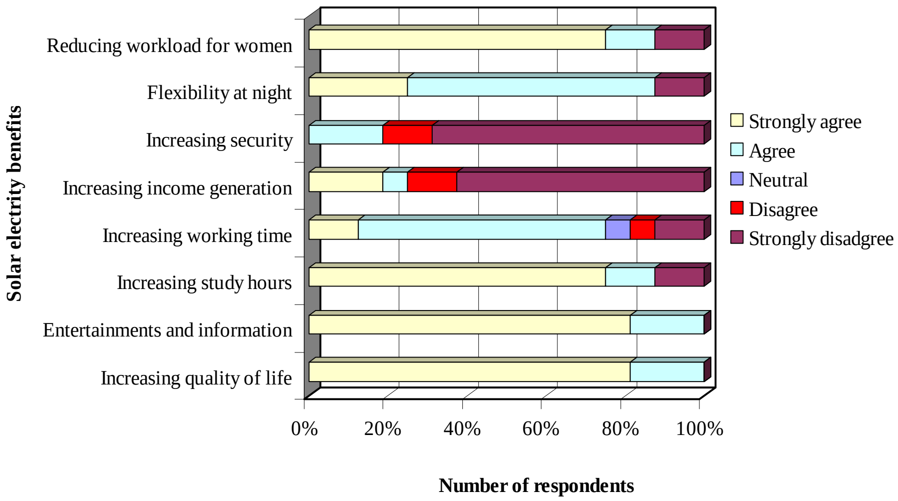

Figure 12 Benefits of solar electricty in the surveyed wards.

It is also shown in Figure 12 that majority of the respondents agreed that solar electricity increased study hours (87.5%), increased walking flexibility in the house (87.5%) and increased working hours after dark (75%). However, most of the households disagree with the statement that solar electricity increased their home security (81.25%). The disagreement probably was due to the fact that solar electricity was normal used for only few hours (approximately four hours) and most households had no outside light.

During the interview, the owners of SHS were also asked to discuss in depth some of the SHS benefits which were not captured in the research questionnaire. In this discussion, teachers indicated that they were able to mark students' home-works and prepare lesson plans during night due to availability of brighter light. In some cases, teachers who had SHSs introduced night classes (tuition). The author considers this as an opportunity for rural students to acquire the same education quality as those living in urban areas. However, the service requires tuition fee, of which parents/guardians could not meet on a daily basis given their low income levels.

One negative effect of solar electricity was reported in one family where a mother complained that she had difficulties of getting her children to study once they had the SHS, because they preferred to sit with the rest of the household members and play cards or watch TV.

System Performance, Limitations and Problems

Solar Home System Performance

Assessing the effectiveness of SHSs is one of the most critical issues not only to the SHS owners but also for the acceptability of the households willing to acquire the new technology. In this research the issue of satisfactions and limitations of the SHSs were examined. Respondents were asked to give their opinion about the performance of their systems. The result (Fåigure 13) shows that more than 88% were satisfied with the performance of their systems while about 6% reported that their system was performing fairly. Due to satisfaction, about 94% of the SHS owners indicated that they would recommend the uses of solar electricity to other households without solar electricity. However, one household indicated that the system was performing very low and therefore he was disappointed. Poor performance for his system was due to poor design and installation as well as the quality of the PV module.

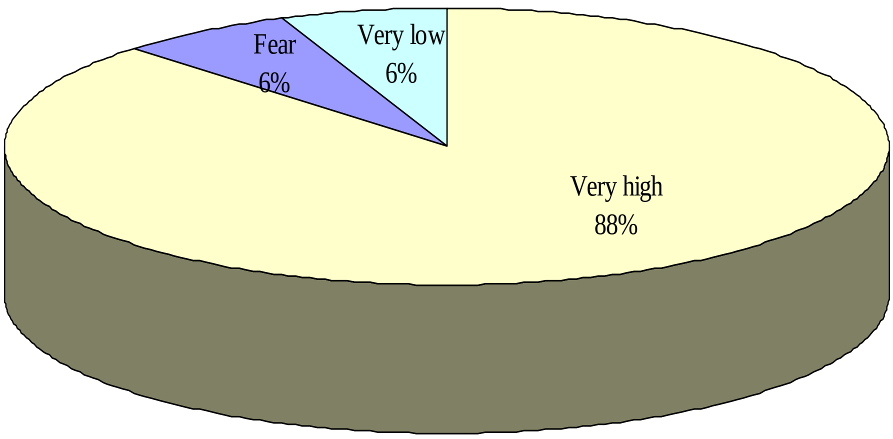

Figure 13: Perception of the SHS owners about performance of their SHSs

Limitations of the Solar Electricity

A disadvantage noted by all the households was the fact that the SHS does not work when there prolonged rain fall and that the system sometimes goes off unexpectedly because it lacks a meter to indicate the presence of energy or remaining energy. For the households whose SHSs had no energy storage, lack of electricity during raining days and heavy cloudy days were expected. Some of the women thought that after obtaining solar electricity they will no longer spend time collecting firewood for cooking and lighting and therefore SHS would relieve them from physical exhaustion. However, this was not the case, since solar electricity is not suitable for cooking and during raining seasons they had to depend on other energy sources for lighting and entertainments.

The fact that the SHS cannot power a small refrigerator was also considered a serious limitation, as this appliance was vey much needed in the three wards. The wards (Karambi, Kasharunga and Kyebitembe) are very close to Lake Victoria and Buringi and therefore some villagers are fishermen both for domestic and commercial purposes. They would like to have a refrigerator to preserve their fish.

Solar Home System Problems

During the interview, the owners of the SHSs were asked if they had any problem with their systems. About 19% reported that their systems had had problems and the main cause of faults in these systems was found to be lack of maintenance. Water loss from batteries occurs rapidly due to the hot and humid climate. The owners reported that it was difficult to get repairs as there were no repair shops near the surveyed wards. The repair shops were located in Bukoba Urban (far way from most of the villages) and technicians are not normally available when they were needed because they were very few. On the other hand, all the households reported that they were not trained even for simple maintenance such water level in the battery and dust clearness on the PV module. The author believes that lack of qualified solar technicians was the main reason as to why there were few SHSs in the surveyed wards.

CONCLUSIONS

In this paper, characteristics, uses, benefits, performance and limitations of the SHSs in the surveyed wards have been presented. Result indicates that installations were of good quality with about 69% of all the surveyed PV modules in pole mounted structure while about 18% were house-roof mounted. However, in some systems, error in placing the PV module (shadowing) and slopping were observed. Unusual SHS was also observed in one household in which the module was mounted directly on the metal roof rather than on a mounting structure that would allow air circulation to cool the PV module and improve its performance.

Most of the households owned small SHS ranging from 10 W to 70 W while large systems were owned by institutional. At the time of this survey, most of the PV modules were working perfect except one system which was performing below its expectation due to degradation and poor designing. Owing to low cost and availability, most of the PV modules (88%) were amorphous silicon whilst the rest were mono-crystalline silicon.

The majority of the SHSs had storage battery and those without energy storage were mainly used during the day time when sunshine was available mainly for mobile phone charging and entertainments purposes (radio-cassette). About 19% and 62% of the SHSs did not have charge controller and DC/AC inverter, respectively. Limited use of inverters was associated with the type of electrical appliances used in rural villages and its cost as well as the availability of skillfully qualified solar electrical technicians.

The main use of solar electricity in the surveyed wards was for lighting purpose whilst access to news and information from TV and radio was ranked the second. Despite the fact that solar electricity was not frequently used for productive purposes, it definitely served to boost business in shops, restaurant, mobile phone charging and motels.

Most of the SHS owners indicated that they were satisfied with the performance of their systems while few (about 6%) reported that their systems wwere performing fairly. Due to satisfaction, about 94% of the SHS owners indicated that they would recommend the uses of solar electricity technology to other households without electricity.

Few systems had problems related to charger controllers and inverters and the owners needed to call the technicians for system repairing. However, there were no repair shops near the surveyed wards. The repair shops were located in the main town, far away from most of the village, and technicians are not normally available when they were needed because they were very few. The author believes that this a main reason as to why there were few SHSs in the surveyed wards. Therefore, efforts must be devoted in training skillfully qualified solar electrical technicians.

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