Illuminated but not electrified: An assessment of the impact of solar home system on rural households in South Africa

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Abstract

The introduction of the off-grid electrification program in South Africa using the Solar Home System (SHS) was a central component of the government policy aimed at bringing development to un-electrified households. An assessment of the performance of SHS in many countries provided little evidence to support the development impact of the system. The general perception is that the SHS program is wasting government funds and has no hope of achieving the set objectives. Previous scientific reports have concluded that SHS is the most viable technology for bringing about socio-economic development to rural households. Most of these conclusions have been based on one sided arguments and largely on anecdotal evidence. This study provides a pluralistic view of the subject from the perspective of the energy service companies (ESCOs) and the households using the equipment. The development impact of SHS is subjected to scientific analysis by investigating the economic and social dimensions of the program. Additionally, the sustainability of the South African SHS program is assessed by investigating the challenges facing the ESCOs and the households. The study reveals that illumination provided by SHS electricity has profound impact on the livelihoods of rural households. Due to the limited capacity of SHS for productive and thermal use, there are limited direct economic benefits to the households. The associated economic impact is peripheral to the secondary usage of SHS electricity. SHS has improved the productivity of small scale business owners who utilize the light from SHS to do business at night. Irregularities in payment of subsidy funds and energy bills, high operation cost, non-optimal use of SHS, grid encroachment, and lack of customer satisfaction contribute to make the business unsustainable for the ESCOs.

1. Introduction

The change in political governance in South Africa in 1994 also led to a major policy review of the energy sector [1]. The government changed the focus of an energy policy based on separate development to an inclusive policy that embraces the energy needs of disadvantaged households. This was evident with the implementation of the National Electrification Program (NEP), a precursor to the Electricity-For-All program of 1994 [2]. The objective in the revised policies is to extend development to the large segments of the population that were deprived during the apartheid regime. One of the basic elements of NEP is the Free Basic Electrification (FBE) policy, which is aimed at providing access to electricity to all South Africans [3]. This policy seeks to provide ways and means through which government interventions can bring about relief to poor un-electrified households and ensure optimal socio-economic benefits from the NEP [4].

In order to achieve this objective the Department of Energy (DOE) awarded contracts to provide electricity to un-electrified rural households to six consortia known as the concession companies or Energy Services Companies (ESCOs) in 2002 [3, 5, 6]. The contract agreement mandates the companies to provide energy services to the off-grid population using the Solar Home System (SHS) [7]. The SHS program has lasted for more than a decade, and on that basis it can be regarded as a success. SHS has been used to facilitate large scale electrification programs in rural South Africa. However, recent reports indicate that the SHS program is fraught with challenges such as inconsistent government policies, theft and vandalization of equipment, limited power capacity and high cost of equipment [5, 8-11]. By 2013 only three of the six concession companies remained in the business, with another on the verge of opting out [10].

Several scientific publications have shown that the use of decentralized renewable energy systems like SHS for rural electrification has become a controversial issue. Many contributions to this topic argue in

support of SHS, while numerous submissions question the efficacy of SHS in bringing about development to rural communities in developing countries. For instance, one report argued that access to electricity can have a significant effect on the livelihoods of households which were previously not electrified [12]. SHS has brought about improved performance for children at schools along with other social benefits like entertainment and cell phone charging [8, 13]. A study conducted in Bangladesh concluded that if SHS is used according to the designed and installed specification, it can improve the quality of life of rural people and provide income-generating opportunities [14]. Results of a survey conducted in Fiji indicate that SHS has improved quality of lives, provided entertainment, enabled increased working and study hours and created jobs, contributing directly and indirectly to increased income generation for the households using it [15].

Meanwhile, several studies have concluded that SHS is not a viable solution for bringing development to the rural population. In another study in Bangladesh analysis of the development impact of SHS shows little evidence that energy from SHS supports development [16]. A review of the effectiveness of SHS in Africa in 2007 questioned the wisdom of using public funds to support SHS at the expense of more appropriate technologies, since the costs associated with SHS remain high for very low service levels compared with conventional technologies [17]. Another challenge is that SHS is limited in scope as basic energy needs like cooking cannot be met [18]. Besides the low power capacity of SHS, the energy conversion efficiency is low and can easily be affected by deposition of dust and other elements on the panels [19]. A review of 232 scholarly articles [20] concluded that despite the social and environmental benefits of SHS the economic case remains uncertain. SHS has been found to be an expensive tool that produces low power at high cost [21]. An analysis of SHS in the Amazonian regions also revealed that the low capacity of the system and low performance during the rainy season is a major drawback [22].

A study in Zambia showed that SHS programs using the concession model forces people into a “solar trap” which often results in protests [8]. Thus, many households do not want to be included in SHS programs for fear of being classified as electrified, thereby risking exclusion from future introductions of

more efficient technologies or expansion of the grid. Another study in Zambia indicates that there is growing resentment towards SHS among households using the system [23]. In addition, the decreasing number of ESCOs in South Africa is an indication that the SHS program is facing challenges [10]. An evaluation of previous reports shows that most conclusions on the subject were based on a one-sided perspective from either users or the energy providers. Furthermore, most arguments lack sufficient evidence to support their case. For instance, the proponents of SHS as a tool for rural development have not explained unambiguously how this might be achieved. On the other hand, those with dissenting argument often ignore the fact that SHS may be useful in some applications. This paper assesses the development impact of the SHS program in specific off-grid locations in South Africa. The socio-economic dimensions of the SHS program and its sustainability are investigated from both the energy providers' and users' perspectives. The intention is to determine the contribution of the SHS program to the development of rural households in South Africa, and whether the adopted method of implementation is sustainable.

Previous studies have shown that there is no agreed definition on rural development. Most definitions responded to regional and local solutions to modernization paradigms [24]. In the past rural development has been associated with growth in the agricultural sector, improvement in social services and reduction of poverty [24]. Rural development was seen as a sustained improvement in the standard of living and/or welfare of the rural population [25]. Rural development has also been defined as an improvement in overall rural community conditions, including economic, social, environmental, health, infrastructure, and housing conditions [26]. This study investigates the ability of the SHS program in South Africa to reduce poverty and induce development of the economic and social lives of rural off-grid households.

2. Fee-For-Service model used for South African SHS program

The contractual agreement between private investors and the South African government led to the formation of local energy providing companies known as ESCOs or concessionaires (because they were given concession to electrify specific geographical locations). The concessionaires are the vehicle used to facilitate the diffusion of SHS electricity in rural South Africa. The government supports SHS and other rural electrification programs with the Free Basic Electricity (FBE) policy and Electricity Basic Support Services Tariff (EBSST), also known as the “poverty tariff”. This policy provides 50 kWh/month of grid electricity for free to all households classified as poor [27]. Households that consume more than 50 kWh/month would pay for their electricity according to blocked or stepped tariffs [27]. SHS users and all non-grid electrified households in South Africa receive a subsidy of 48 ZAR per month for payment of electricity service charges [6]. The ESCOs are made up of both local and international entrepreneurs who invested private funds with the intention of recovering their investment through service charges from customers. A government subsidized Fee-For-Service finance mechanism is currently being used to run the program. Under this financing structure, the households pay for services only, but allow to keep and use the systems without owning it.

The organizational structure of the fee-for-service business model is shown in Fig. 1. The Department of Energy (DOE) and the National Electricity Regulator of South Africa (NERSA) bankroll and regulate the program respectively. Under the contract agreement, the government is responsible for 80% of the program’s funding, while the remaining 20% comes from private investors. The ESCOs are solely owned by private investors [3]. The households pay the maintenance and service charges by purchasing tokens from energy stores [5]. The ESCOs administer the provision of SHS and auxiliary energy services like LPG, paraffin, and stoves to the households in their concession areas [5, 7]. The energy providers run their operations from branch offices and energy stores located close to their customers, including services such as logistics for installation and maintenance, and stocking and refilling of LPG and paraffin.

Fig. 1. Organizational structure and Fee-For-Service model of the SHS program in South Africa.

3. Study areas and methodology

The study was conducted between the 16th of April and 1st of May 2013 in seven villages in four municipalities located in three provinces of rural South Africa (see Figs. 2 and 3). Technical and management staff of the ESCOs, namely Solar Vision, NuRa Energy and Kwazulu Energy Services (KES)¹ were interviewed along with a number of households.

¹ The management and technical staff of Kwazulu Energy Services' concession areas in southern Kwazulu-Natal and northern Eastern Cape were interviewed, but households in these areas were not interviewed.

Fig. 2. Surveyed areas and the stakeholders interviewed.

Fig. 3. Map of South Africa showing the location of the surveyed villages.

3.1 Assumptions made in the study

The assumptions made in the study were: cost of energy is directly proportional to size of household; the pattern of energy usage is uniform in all the households; cost of fuel excludes transportation; service charge is considered as the total burden of SHS (because purchasing and installation cost is covered by subsidies, hence no additional burden on the household); a five person household is used as the base case; candles and paraffin are not used to provide lighting when there is a power outage from the SHS. The foreign exchange (FOREX) at the time of the investigation is \$1 USD to ZAR 9.

3.2 Data gathering through semi-structured interviews

Data was collected through semi-structured interviews supervised by a team of researchers from Mälardalen University, Sweden, assisted by trained interviewers who speak the local languages. The translators were considered necessary to gain the confidence of the interviewees and to allow for more flexibility in the discourse. For the analysis, the survey was categorized into households in the Solar Vision and NuRa Energy concession areas. The Solar Vision concession area includes households in Polokwane municipal area comprising Thlatlaganya village with 23 surveyed households, Vhembe municipality (Muchipisi and Masakele villages) comprising 24 households, and Greater Tubatse municipality (Malaeneng village) with 23 households. The NuRa Energy concession area includes households in Umkhanyakude district municipality, comprising (Mzinyeni, Khwambusi and Ndumo villages) with 18 surveyed households. A total of 88 households were interviewed in the seven villages. The dispersed nature of homesteads in the NuRa concession area explains the shortfall in the number of households surveyed in Umkhanyakude municipality.

3.3 Social impact of the SHS program

The assessment of the social impacts of SHS on the households was analyzed using parameters such as satisfaction with SHS electricity, its ability to meet energy needs, theft of solar panels, influence on skills acquisition, and impact on children's education.

3.4 Economic impact of SHS program

The economic impact of SHS was evaluated using household income, income distribution, cost advantage of SHS over alternatives, improved economic activities as a result of SHS and energy burden of SHS and alternatives. Energy burden is defined as the share of a household's income that is devoted to energy

expenditure [16]. In this study energy burden represents the percentage of the household total income that is paid for energy services.

In the analysis of the energy burden 10% of the household total income was used as the threshold for determining the energy poverty line. 10% of income has been used as the threshold for energy in many studies [28-31].

The economics of SHS energy in comparison to alternative energy sources was determined by comparing the energy burden of SHS on the household with those of LPG, paraffin and candle. Two scenarios were investigated for the energy burden. The first was the energy burden of households with access to SHS electricity. In this case, SHS was considered as the only energy source for lighting, alternative energy sources like paraffin, firewood and LPG were used for cooking. In the second scenario, households without access to SHS electricity were investigated. Alternative energy sources such as candle and paraffin (lantern) were used for lighting, while paraffin (stove), firewood and LPG were used for cooking. The cost analysis for various energy sources was based on the data from Table 1.

Table 1. Cost analysis for alternative energy sources

Energy source	Cost/Unit [ZAR]	Quantity	Combined cost [ZAR]	Cost for a household of 5 Cost [ZAR]
Wood [kg]	2.2	10	22	110
Paraffin [liter]	10	25	250	250
LPG [kg/m ³]	23	19	437	437
Candle [per pack]	15	5	75	75

Source: Author's compilation base on personal communication and [32, 33].

4. Results

4.1 ESCOs' Perspective

The interviews with the ESCOs revealed some of the benefits and challenges facing the South African SHS program. According to Solar Vision, increased illumination at night provides protection against reptiles and reduces the rate of theft in the villages. It has also reduced the use of candles thereby decreasing the risk of fire accidents. In addition, improvement in children's education by extending possible study hours have also been observed. The responses from the ESCOs show that access to information and entertainment is the most noticeable social impact of SHS electricity.

Due to a number of challenges, sustainability of SHS has been difficult to achieve for the ESCOs despite government support through subsidies. The ESCOs are currently grappling with the issue of delayed payments of subsidies from some municipalities. The tariff for the SHS service ranges from 60 to 70 ZAR/month, and the EBSST supports poor households with up to 48 ZAR/month, depending on the municipality. A household can pay up to 30 ZAR/month, however, over the years some municipalities have stopped paying the EBSST subsidy. For instance, out of the five municipalities within the NuRa Energy concession area only one is still paying the subsidy. This has compelled NuRa Energy to increase the energy tariff, which is currently causing disaffection with SHS in some households for whom the increased price is not reflected in the service provided. According to our analysis, the average energy bill is 110 ZAR/month in the NuRa Energy concession area and 27 ZAR/month in the Solar Vision concession area.

Non-payment of service charges by some households is another issue that increases the financial burden on the ESCOs. Other challenges that the energy providers face are frequent theft of solar panels, user ignorance and lack of responsibility and abuse of SHS, e.g. bypassing of charge controllers to gain direct access to electricity from the battery. In addition, the ESCOs have to contend with vandalization of equipment, illegal use of cheap inverters that draw disproportionate amounts of current from the system, preference of grid electricity to SHS, and unplanned encroachment of the Eskom grid. Incorrect usage of

the systems mostly affects the battery, resulting in more frequent battery replacements, adding to the operation and maintenance costs.

4.2 Households perspective

The results from the household survey are divided into two segments. The first segment represents the responses regarding the social impact of the SHS program on the households, while the second segment deals with the economic impact. The analysis also compares the impact of SHS electricity on households in the Solar Vision concession area which are supported by the EBSST subsidy and the households in the NuRa Energy concession areas whose municipalities have ceased payment of the poverty tariff.

4.2.1 Assessment of social dimensions of SHS on the households

The results presented here represent the social impact of the SHS program as perceived by the respondents.

4.2.2 Satisfaction with SHS

The survey indicates that the level of satisfaction with SHS services is lower than the level of dissatisfaction. 56% of the households interviewed are not satisfied with SHS services, while 44% rated them as satisfactory, with ratings of excellent, very good or good. However, the level of satisfaction varies between villages depending on their specific circumstances. Masakele village (Vhembe municipality) for instance reported 90% satisfaction, while Malaeneng village (Greater Tubatse municipality) reported only 13% satisfaction. Villages like Thlatlaganya (Polokwane municipality), Malaeneng (Greater Tubatse Municipality) and Ndumo (Umkhanyakude municipality) reported levels of dissatisfaction above 50%, with Malaeneng having the highest with 87% (Table 2). There is no noticeable distinction in the attitudes of the households in the two concession areas (NuRa Energy and Solar Vision), with as many as 56% of all respondents in Solar Vision and NuRa Energy concession areas reportedly dissatisfied with their SHS. The average results by municipality are shown in Table 2.

Table 2. Households' satisfaction ratings regarding SHS electricity in the four municipalities

Satisfaction with SHS	Polokwane n=23	Vhembe n=24	Greater Tubatse n=23	Umkhanyakude n=18
Excellent (%)	0	12	4	5
Very good (%)	4	13	0	11
Good (%)	39	50	9	28
Not satisfied (%)	57	25	87	56

4.2.3 Influence of SHS on skills acquisition

Interviewees were asked to describe how SHS had influenced their ability to develop skills, with the aim of identifying the impact of SHS on human capital capacity building. 41% of all the households interviewed stated that SHS has had positive impacts, while 59% were uncertain. The responses vary between villages, but households in the Solar Vision concession area reported more positive impacts on their skills development than those in NuRa Energy areas, with values of 47% and 22% respectively. While there is a high level of ambivalence in all households none indicated that SHS has had a negative influence on skills acquisition (Table 3).

Table 3. Reported effects of SHS program on skills acquisition.

Skills acquisition	Polokwane n=23	Vhembe n=24	Greater Tubatse n=23	Umkhanyakude n=18
Positive (%)	48	46	48	22
Negative (%)	0	0	0	0
Uncertain (%)	52	54	52	78

4.2.4 Meeting of energy needs with SHS electricity

Many factors influences the energy needs of a household, including income, job type and routine, age, household size, and social status of the inhabitants. The assessment of the ability of SHS electricity to meet these diverse energy needs indicates that it seldom does. For instance, in the NuRa concession area

89% of the respondents reported that their energy needs are not being met, while as many as 67% reported alike in the Solar Vision area (Fig. 4). A majority of respondents said that they only use their SHS for lighting for a limited period during the day. Heating and cooking are done mainly with paraffin and firewood, and a few households use LPG to meet their thermal energy needs.

Fig. 4. Reported ability of SHS electricity to meet the energy needs of households.

Responses from households regarding the ability of SHS to meet energy needs show that 11% of households in Kwazulu-Natal is meeting their energy needs with SHS, since they do not have much demand other than lighting and charging of phones, while 89% have had issues with the system such as insufficient power, decline in performance 3-4 months after installation, weak batteries that can't even sustain the lights, insufficient power to support appliances like cooking stoves, pressing iron, color TV, refrigerator, and the system breaking down with the slightest use. All the respondents in Greater Tubatse have had issues with the power from the system, they complained that their usage of the system is limited due to its low power. In Vhembe municipality 42% responded that their energy needs are limited, and therefore the electricity from SHS is meeting their needs, while 58% complained that the power from the system does not enable them to use their appliances, which stand idle most of the time. 13% of households in Polokwane indicated that their power needs are being met, while 87% responded negatively. Many

complained that they are unable to store perishable foodstuff, the electricity cuts off when all appliances are switched on at the same time, and that SHS cannot support appliances other than lighting, charging of phones, radio and DC-TV.

4.2.5 The effect of SHS on children's education

Responses indicate that before the introduction of SHS most children preferred to do their homework during the day, and few were able to study at night using candle and paraffin lighting for limited hours. SHS therefore offers an alternative source of lighting to meet this demand. The result shows that in both concession areas, SHS has affected children's education positively. In NuRa Energy concession areas 89% of households said that SHS has positive effects on their children's education, and 84% indicated likewise in the Solar Vision area. The rest of the respondents in the two areas were uncertain on the impact of SHS on children's education. A majority of those that were uncertain on the impact of SHS includes those with adult children and infants who are either out of school or not yet in school. None of the households stated that SHS has a negative influence on their children's education (Table 4). Discussions with some of the respondents revealed that the positive effect is a consequence of the extended hours available for learning due to the greater availability of illumination at night. A majority of the respondents indicated that lighting is the most important contribution of SHS due to its positive effect on their children's education.

Table 4. Reported impact of SHS on children's education.

Impact on education	Polokwane n=23	Vhembe n=24	Greater Tubatse n=23	Umkhanyakude n=18
Positive (%)	92	83	78	89
Negative (%)	0	0	0	0
Uncertain (%)	8	17	22	11

4.2.6 Theft of solar panels

One of the social ills facing the SHS program in South Africa is the theft of solar panels. A majority of the respondents have experienced theft of solar panels at one time or the other. Awareness of solar panel theft

is high in both concession areas. 89% of the respondents in the NuRa Energy concession area indicated that they are aware of solar panel theft, while 61% agreed that the frequency of occurrence is high. 61% indicated awareness of solar panel theft in the Solar Vision area and 41% stated that it is frequent. The awareness and frequency of theft indicates that solar panel theft may be more prevalent in the NuRa concession area (see Table 5). Even so, Thlatlaganya village in Polokwane municipality has the highest awareness and occurrence of equipment theft.

Table 5. Reported awareness and frequency of occurrence of solar panel theft.

Municipal area	Awareness of theft		Frequency of theft	
	Yes [%]	No [%]	Frequent [%]	Not frequent [%]
Polokwane (n=23)	91	9	83	17
Vhembe (n=24)	63	37	29	71
Greater Tubatse (n=23)	30	70	11	89
Umkhanyakude (n=18)	89	11	61	39

4.3 Assessment of economic dimensions of SHS on the households in rural South Africa

Explicit questions were asked on the level of economic activities and the influence on development to ascertain the impact of SHS since the start of the program.

4.3.1 Income and payment capability of the households

Most households in the surveyed areas depend on grants, pensions, remittances and incomes as labourers from neighbouring farms for subsistence. Therefore, the average household income in the surveyed areas is low when compared to municipal and provincial household incomes. According to the survey, the average income per household in the NuRa Energy concession was 1941 ZAR/month and that in the Solar Vision was 1428 ZAR/month as shown in Table 6.

Table 6. Household income and SHS charges.

Municipalities	Average income [ZAR]	Average size of household	Average service charge [ZAR]
Polokwane (n=23)	1605	5	29
Vhembe (n=24)	1275	4	29
Greater Tubatse (n=23)	1405	6	23
Umkhanyakude (n=18)	1941	7	110

4.3.2 Analysis of income distribution and payment of service charges

With a mean income distribution of 1941 ZAR and 1428 ZAR for NuRa and Solar vision concession areas respectively, the statistical analysis shows that the non-overlapping confidence intervals (Fig. 5) indicate a significant difference in income between the two concession areas. The study also shows a mean of 110 ZAR and 27 ZAR in the ability to pay service charges in the NuRa and Solar Vision areas respectively. The non-overlapping confidence intervals also demonstrate that there is a large difference in the service charges between the concession areas (Fig. 6). The disparity is due to the lack of an EBSST subsidy in the NuRa Energy concession area.

Fig. 5. Average income and confidence interval for NuRa and Solar Vision concession areas.

Fig. 6. Average SHS service charge and confidence interval for NuRa and Solar Vision concession areas.

4.3.3 Cost advantage of SHS over alternative energy sources

The energy sources commonly used for cooking in the surveyed villages are firewood, paraffin and most recently LPG. Table 1 was used to analyze the cost benefit of SHS over the alternative energy sources. The burden of an energy system on a household is evident when the energy expenditure is expressed as a percentage of the household income (Fig. 7-9).

4.3.4 Analysis of energy burden for households with access to SHS electricity

The analysis of the energy burden of SHS on the households showed that households within the Solar Vision concession area, which receive the EBSST subsidy have lower energy burden, and spend an average of around 2% of their monthly income on the SHS energy bill. Whereas households in the NuRa concession area spend up to 6% of their monthly income on the SHS energy bill. When the cost of firewood is taken into account, most households in Greater Tubatse (Solar Vision area) spend around 10% of their income on energy (Fig. 7). In the NuRa concession area, in the absence of the poverty tariff, the energy burden rises to 14% of the average income. The combination of SHS and paraffin to meet energy needs increases the energy burden to around 21% of their income. The few households that use LPG for cooking and SHS for lighting, had an average energy burden of around 34%. It is therefore safe to conclude that the households are energy poor when the total energy needs are taken into account. However, the household SHS energy expenditure alone is less than 10% of their income with or without the EBSST subsidy.

Fig. 7. The energy burden on the average income² of households with access to SHS.

4.3.5 The cost analysis for households without access to SHS electricity

Households that use candles for lighting and free firewood for heating spend an average of 5% of their income on energy (Fig. 8). However, those that pay for firewood, and to greater extent those that use paraffin and LPG for cooking, exceed the 10% energy burden threshold and therefore could be considered as energy poor (Fig. 9).

² Note the average income indicated at the foot of the bars under each municipality represents the mean income of the households interviewed during the survey. The values on the y-axis represents the share of the household income spent on a particular energy source.

Fig. 8. Energy burden on the average income of households using candle for lighting.

Fig. 9. Energy burden on the average income of households using paraffin for lighting.

4.3.6 Economic development impact of SHS on the households

Responses from the survey indicate that the influence of SHS on household economic development is minimal, as shown in Table 7. Its ability to jumpstart small scale businesses is generally low in the surveyed regions. 23% of all the households believed that SHS has a positive economic impact on their livelihood, 47% did not believe so and 30% were uncertain. Respondents in the Solar Vision concession area were more positive (25%) than those in the NuRa Energy area (17%), Khwambusi village (Umkhanyakude municipality) was the only village in the survey where more than 50% of responses were positive regarding the ability of SHS to stimulate small scale businesses. Three quarters of all the households reported that SHS has not led to any job creation or increased chances of employment. 83% of households in the NuRa Energy concession area and 75% of households in the Solar Vision area either did not agree or were unaware of any business started as a result of the SHS program.

Table 7. Reported economic activities resulting from the SHS program.

Impact on economic activities	Polokwane n=23	Vhembe n=24	Greater Tubatse n=23	Umkhanyakude n=18
Yes (%)	35	17	22	17
No (%)	61	33	65	27
Uncertain (%)	4	50	13	56

5. Discussion

5.1 Development impact of the SHS program.

According to the UN standard that places the poverty line at purchasing power parity (PPP) of \$1.25 per day [34], the surveyed households lie below the poverty line. The analysis shows that the average monthly income per head per day is \$1.03 in the NuRa area and \$1.06 in the Solar Vision area. According to a statistical report, the average income for Polokwane, Vhembe and Greater Tubatse municipalities are 5768 ZAR, 4120 ZAR and 3831 ZAR/month respectively, the province average (Limpopo) is 4737 ZAR/month, the average income for Umkhanyakude municipality is 3933 ZAR/month and the province average is 8600 ZAR/month [35, 36]. The income of the households in the surveyed concession areas are

far below the provincial and municipal averages. Therefore, they can be classified as poor in both world and South African standard. The SHS program and the Fee-For-Service model took the low income of the households into consideration in the implementation of the program through the EBSST subsidy. The high variability in the SHS service charges between households in the NuRa Energy and Solar Vision concession areas is indicative of the fact that most municipalities in the NuRa Energy territory are no longer paying the EBSST subsidy. This has increased the energy expenditure of households within the concession areas three fold. Government support through subsidy is also reflected in the comparative cost advantage of SHS over the alternative energy sources. The energy burden on households with access to SHS is lower than households without access to SHS that use candle and paraffin for lighting. Including the cost of thermal energy sources results in most households (with or without the EBSST subsidy) exceeding the 10% energy burden benchmark. They can therefore be regarded as energy poor [30]. Although the study shows an average expenditure on SHS electricity below the 10% threshold, the 80% funding from the government was excluded from the analysis. If this is included, households without EBSST support would spend about 30% of their income on SHS electricity. However, free gathering of firewood is the prevalent practice in most of the villages during the survey.

The responses show that illumination provided by SHS has a positive effect on children. Extended reading hours are accompanied by flexibility in reading routines, improving educational outcomes. This result is consistent with a similar study which showed that the introduction of SHS in rural households in Zambia improved children's performance at school [23].

Analysis of the data from this study shows that the SHS program has limited direct economic impact on the households. This is mainly due to the limited capacity of the system. Responses show that there is a high level of uncertainty regarding the economic impact of the SHS program on the households. Even those that agreed that it has positive impacts, could not explain unambiguously in economic terms the specific development impacts of SHS. The situation is exemplified by one respondent saying that the only

job SHS has created in the village is that of the technician who makes a brisk business illegally bypassing the control units.

The only perceptible economic impact of SHS revealed by this study is related to illumination provided by SHS electricity. Those who have benefitted economically from SHS are those who use illumination from it to extend business hours into the night. For instance, some respondents in Khwambusi village indicated that SHS has helped their grass mat making business, since working late at night has greatly improved production and significantly reduced expenditure on candles. Discussions with some households revealed that SHS has an economic impact on small scale businesses like retail tuck shops, hairdressers, barbers and provision stores that utilize the light provided by SHS to work late at night. A tuck shop owner from Malaeneng village admitted that his business hours have been extended from his normal closing time of 20:00 to 23:00, and he no longer has the problem of issuing the wrong change to customers, which was not the case when paraffin lanterns and candles were used.

However, the assertion that extended business hours and reading periods could lead to an improvement in businesses and performance at school should be taken with caution, because although activities are able continue into the night, it is difficult to conclude that there is an improvement in outcomes without further research. This situation reiterates the argument of [16] that extending business hours does not necessarily translate to an increase in sales and that changing of children's reading routines does not necessarily lead to improved performance at school, since spending more time with a customer who decides to shop at night instead of during the day does not necessarily lead to increased sales, and children who spend day watching TV and read at night may not do better at school. Even if the illumination from SHS electricity does improve the economies of a few isolated households engaged in business activities at night, this does not necessarily translate to a sustained socio-economic development in the local communities. In addition, watching TV, listening to the radio, charging phones and doing business at night are neither parameters nor indices for measuring development as stipulated by [26].

5.2 Sustainability of SHS program

Information from the ESCOs shows that the sustainability of the SHS business under the present condition is low. The ESCOs are currently grappling with issues of delayed payments of the EBSST subsidy from some municipalities, and contending with poor payment capability of some households due to low income. Grid encroachment and the setting of unrealistic targets by the department of energy also weigh down on their activities. The most worrying challenges currently facing the SHS program are the issues of equipment theft and non-optimal use of the system due to lack of user education. Abuse of the system through tampering, vandalism and bypassing of control units are added challenges that adds to the overhead maintenance and operation costs. These challenges negatively affect the sustainability of the SHS program in South Africa and may be the reason why three of the six ESCOs who were originally awarded the SHS contract have withdrawn from the program.

The assessment of social impacts of the SHS program on the households reveal that a high percentage of respondents are not satisfied with their SHS, and that those that showed high levels of satisfaction, like in the case of Masakele and Muchipisi in Vhembe municipality acquired their systems in February 2013, just prior to the survey and are located far from the grid. Experience has shown that with increasing load and non-optimal use of the systems, the battery systems soon succumb to abuses and overloads which lead to power outages and then disaffection with the system. This is consistent with the position of [37] who advised that electricity demand soon doubled after installations due to increasing load. On the other hand, villages that indicated high levels of dissatisfaction with SHS like Malaeneng (Greater Tubatse), Thlatlaganya (Polokwane) and Ndumo (Umkhanyakude) have peculiar circumstances. For instance, in Malaeneng the Eskom (the major power utility company in South Africa) grid passes through the village to the neighbouring farms. In Thlatlaganya the grid exists side by side with SHS and in Ndumo village the Eskom power grid is only a few kilometers away. Proximity to the grid creates awareness and makes the limitations of SHS more apparent to the users, which contributes to hostility towards SHS over time. This also affects the sustainability of the program.

The results from the survey show that SHS is not meeting the energy needs of the households interviewed. A majority of the respondents admitted that they could only use their SHS for limited hours. Those who indicated that SHS is meeting their energy needs nevertheless request that government should improve the power quality so that they can use some of their idle appliances. SHS electricity is currently used for lighting, entertainment using radios with a low power rating or a black and white DC-TV, and phone charging. Therefore, it has little or no effect on skills acquisition since it cannot be used for any productive purposes due to the limited power capacity. These findings agree with studies like [18, 21, 22] which report on the challenges of the low power limitations of SHS. Sustainability of the South African SHS program under these conditions is therefore unlikely.

6. Conclusion

Analysis of the impact of the solar home system program in South Africa revealed the following salient points.

- Illumination provided by SHS electricity has a positive impact on the households, it has enabled increased access to information and entertainment, and could affect children's education positively.
- The direct economic impacts of SHS are uncertain and difficult to evaluate due to the absence of verifiable supporting evidence. Peripheral economic, and social impacts of SHS are associated with the secondary usage of SHS electricity. It has provided useful illumination which supports business activities at night.
- The energy needs of households are largely unmet by SHS due to the limited power of the system. This has a negative effect on the households' satisfaction with the system.

- Proximity to the grid creates awareness of the thermal and productive capacity of the national grid resulting in resentment of SHS.
- Grid encroachment, irregular payment and non-payment of energy bills by some municipalities and customers are making the SHS program unsustainable for the ESCOs.
- In addition, equipment theft, non-optimal use and abuse of SHS are increasing the cost of doing business for the ESCOs.

There is no evidence for specific development impact resulting from the implementation of the South African SHS program. Most of the measurable socio-economic impacts are hampered by the limited power from the system. However, further research is needed to compare the pre and post SHS periods of South Africa with regard to socio-economic conditions before a rigorous conclusion can be drawn. However, the current situation on the ground shows that SHS households are poor in both economic and energy terms.

6.1 Recommendation

Based on the information from the study there is an urgent need for education of households on the designed and operational guidelines of SHS, since abuses and non-optimal usage of the systems are increasing costs for the energy providers and by extension threatening the sustainability of the program.

Strict FBE policy implementation by the government, transparency and adherence to the approved grid extension plan by Eskom could forestall the issues of grid encroachment, institutional delays and payment avoidance by some municipalities. Also empowering the poor households through supports for upstarts of small-scale businesses could contribute to increase in payment capability and improved livelihood. In addition the power supply from SHS needs to be improved to drive productive activities which are necessary for sustaining businesses, without which the socio-economic development objective of the government is likely to remain unattainable.

Despite the shortcomings of SHS, it may still be useful for providing supplementary electricity for lighting during power outages in locations that are already connected to the grid. Moreover, locations that are not going to be connected to the grid in the foreseeable future could utilize SHS electricity for lighting. However, the inhabitants of such locations should not be expected to depend on SHS electricity for income generation because of the low power output from the current systems being provided by the government through the ESCOs.

Acknowledgements

We thank the locals of Thlatlaganya, Masakele, Malaeneng, Muchipisi, Dumela, and Ndumo communities for their hospitality and valued information given to us during the survey. Our profound appreciation goes to Jake Jacobs, the MD of Solar Vision whose support made the survey a success. We also thank Sifiso Dlamini, the general manager of NuRa Energy, for coordinating our survey in Kwazulu Natal province, and we must not fail to mention the positive contribution provided by Vicky Basson, the MD of Kwazulu Energy during her interview. Special thanks to the Department of Energy of South Africa for the valid information and support given to us during the study. We would like to acknowledge the Swedish International Development Cooperation Agency (SIDA) for their financial support under the contract AKT-2010-031.

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