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The impact of solar home systems on rural livelihoods. Experiences from the Nyimba Energy Service Company in Zambia

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Abstract

An Energy Service Company (ESCO) in the town of Nyimba, Zambia, has been operating 100 solar home systems since the year 2000. The company is part of a pilot project implemented by the Government of Zambia with the aim to apply the ESCO concept for diffusion of solar technology. The change in livelihood as a result of the access to electric services has been investigated in a survey. Clients were satisfied with the services they receive, although they are paying more than previously for energy. Light hours did not increase, but the quality of light was improved, enabling activities such as domestic work at night and studying for longer hours. Many of the clients had acquired TV and video, and become part of a more global culture. Appliances for entertainment, such as video and TV, were considered more attractive than productive appliances such as a water pump by many respondents. In some cases also people from households without solar installations benefited from the installations, for instance, children gathering in houses with solar to study at night.

Keywords: Zambia; Solar photovoltaic; Energy service; ESCO; Livelihood; Rural households; End-use appliances

1. Introduction

In Sub-Saharan Africa, the access to electric power is highly restricted and few countries can claim that more than 20% of the population have access to

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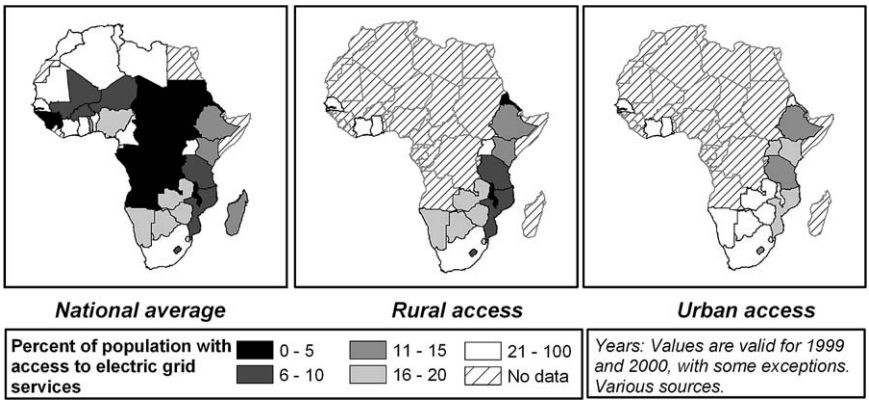

Fig. 1. Electrification rates in some African countries.

electricity. In the rural areas, electrification levels are lower than national averages, often at 1–2% (Fig. 1). For most people in the rural areas, electricity is only acquired from dry cells, for running a radio or a torch. Most know about grid power only through hearsay or visits to larger towns. In some areas, people are using car batteries which they carry long distances for charge.

In recent years several efforts have been made to popularise solar photovoltaic (PV) technology in order to supply energy services to people without access to an electric grid connection. Although the price for solar PV panels has decreased over the years, the costs are still too high for most rural farmers or potential solar home system (SHS) users [1]. There have been several projects to popularise and disseminate solar technology in Africa. In Kenya, a substantial success has been reached by relying largely on market forces [2,3]. Zimbabwe [4,5], South Africa [6,7] and Ghana [8] have launched ambitious programmes with strong government backing.

Bilateral and/or multilateral organisations are playing important roles as funders for these solar PV projects. Turkson and Wohlgemuth [9] argue that many of these projects are pilot projects and not a deliberate result from Government or utility policies. While initial dissemination has been rather successful through the large government programmes, the long-term functioning of the structures built up has been poor. Although attempts were made to promote local suppliers and service capacity, most of the subsidies went to large entrepreneurs without sustainable operation once external financing ended. Smaller suppliers are often disqualified, which results in severe market distortions [5,10]. Political pressure in the allocation of resources has also impeded the development [11].

During the 1990s, it has become increasingly clear that solar PV should not be marketed as a functional hardware, but as a service package, where clients essentially by the products (services) of the system—light, possibility to play music, watch TV—but not the system itself. This is an approach initially applied in the Pacific, where the term Energy Service Companies (ESCOs) was first used

[12]. Successful experiences have been reported from projects in, for example, Dominican Republic and Sri Lanka [13]. The ESCO sells light (service from the solar system), and provides maintenance and repair (service of the solar system), something that often lacks in conventional top–down approaches [14].

The ESCO concept was also much in line with the changes in development policies that took place in the international and multinational institutions. For many years development assistance had been supply oriented, implying that the projects were aimed at supplying an energy technology or an energy source to the beneficiaries. But during the 1990s the shift towards more people-oriented development interventions took place. Market-oriented approaches to development became the leading word for successful projects. The ESCO concept in this sense was perfect as well. However, although the ESCO concept is market oriented, the technology that is promoted and diffused, in this case solar technology is still chosen through a top–down method.

This paper presents initial findings on the clients' experience of an ESCO project in Nyimba town, Eastern Province of Zambia.

1.1. The Zambia PV ESCO project

The Zambia PV ESCO project was started in June 1998. It is implemented by the Department of Energy (DoE), Government of Republic of Zambia. It is supported financially by the Swedish International Development Authority (Sida), with the Stockholm Environment Institute (SEI) as advisors to the DoE. It is a pilot project with the aim to investigate whether the PV ESCO approach is appropriate and can be integrated in the rural electrification strategy of Zambia.

The project has supported the formation and operation of three ESCOs in the districts of Nyimba, Lundazi and Chipata in Eastern Province of Zambia. In all cases, the ESCO business is a subsidiary to an existing company with business activities in other fields: farm implements, waste management and a farmer's cooperative. The ESCOs are private companies and are licensed to do business and installation of solar equipment by the Energy Regulation Board (ERB). The mother companies were selected from an application process, where they had to demonstrate their willingness and ability to perform the services, and formulate a business plan that included budgets and future development plans. The ESCO project has also offered the companies' technical training, as well as business training.

A battery fund is a central function in the Zambia PV ESCO project design. This is a savings scheme, where part of the regular service fee is set aside in a bank account, in order to be able to purchase a new battery once the present battery is exhausted. The fund is at present managed by the DoE, but a transfer of management to an autonomous institution is to be expected.

The ESCO in Nyimba has operated for almost 3 years and is servicing and maintaining a total of 100 SHS at a fee paid by the clients. The hardware is at present the property of GRZ, but a system for transfer of ownership to the ESCO is being designed [15]. This will result in an increase in the service fee.

Nyimba is the district capital of Nyimba district situated 300 km East of Lusaka and in 2000 the district population was 63,000 [16]. The main occupation is small-scale farming. Nyimba is not yet electrified and is one of the few district capitals in Zambia without electricity. One of the reasons is that the district is relatively new and due to this, grid extension has not been prioritised. There is no telephone connection in the town, and no national television broadcast.

1.2. Specification of systems

The procurement of the solar equipment and the installations had to be made through the official governmental channels, a process that created delays for the ESCOs to receive equipment. Specifications of the systems were based on experiences from other solar power projects, consideration of usefulness and affordability, and surveys of energy use and affordability in the Eastern Province [17]. A standard system size of 50 Wp was chosen to provide useful light in the night to a household of 5–6 persons in the area (Table 1). The companies were to include installation and training of ESCO technicians in their bids.

The winning bid came from Electric Maintenance Limited (EML), a Lusaka-based company. One hundred systems were installed in four batches each of about 25 systems, during a 9-month period. Panel, batteries and charge/discharge controllers are imported items. The Energy Regulation Board (ERB) has made inspections of each of the installations. Their report shows that, after some adjustments, these have filled the requirements set in the procurement documents.

Table 1
Specification of systems, NESCO

General	No. of systems	100
	Year procured	1999
	Contractor	Electric Maintenance Limited (EML), Lusaka
	First installation	April 2000
	Installations ready	December 2000
Panel	Watt peak	50 Wp
	Manufacturer	Siemens
	Placement	On roof, adjustable or pole mount. EML design
Battery	Manufacturer	First National Battery
	Type	Leisure Pak, RR2
	Watt hours	96 Ah
	DOC 80%	250
Controller	Manufacturer	Siemens
	Model	SR20
Lamps	No. of lamps	4
	Watt	7 W
	Type	Fluorescent
Installation material	Installation made with conduit pipes, lamp sockets and switches. One double 12 V socket installed	
Price per system	USD	917

2. Method

In June 2001, a survey was carried out targeting all 92 clients of Nyimba ESC Company, with a total of 100 SHSs. The aim was to collect information on the impacts on the livelihood system as a result of access to electric services such as light.

In order to illustrate differences between households with SHS and those without, neighbours to the SHS respondents were also targeted in the survey. For each SHS client, the nearest neighbour was interviewed. This gave information about the neighbour's knowledge about solar power and the possibility to buy electric services through a local ESCO. The clients to NESCO are found in 10 groups along the Great East Road (Fig. 2). Two-thirds of the systems are found within 1 km of the main office in Nyimba town. The most distant systems are located 44 km to the west of Nyimba.

A census sample was used, i.e. all the users were interviewed. The design of the questionnaire was based on deep interviews with a few clients and the questionnaire was tested and adapted. Local enumerators were trained and used to fill in the questionnaires. These enumerators were accompanied by one of the ESCO's technicians, who introduced the enumerator to the person in the household. GPS receivers were used to identify each SHS location geographically. Local enumerators were used and these were accompanied and introduced to the clients and neighbours by the technicians who then left during the interview. The respondent

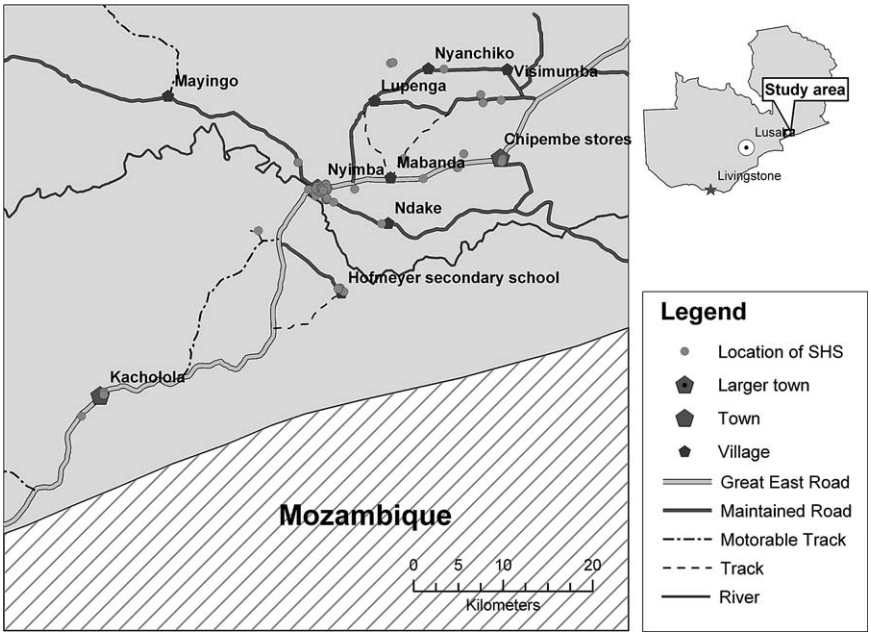

Fig. 2. NESCO operation area, locations of SHS and client groups.

could be anyone in the households, i.e. it did not have to be the person who had signed the contract with NESCO.

3. Results

3.1. Fees

In 2001, the users paid a monthly service fee of Zambian Kwacha (ZMK) 25,000 per month (USD 6.85/month).[1] ESCO clients were paying substantially more than their neighbours for energy services, including electric items (dry cell batteries, service fee for NESCO, car batteries and generator power) and other light sources (candles, paraffin). The expense on energy services per household was ZMK 28,000 for clients and ZMK 19,000 for neighbours. Most respondents considered their expenses on these items as high, with a greater majority among the clients (85%) than among the neighbour group (68%).

A comparison between expenses on cooking fuel and those for electricity services and light shows that cooking fuel represents 30% of the total expenses on these items for the clients and 36% for the neighbours. The relatively low cost share for cooking fuel comes from the fact that many use wood for cooking fuel, which can be gathered for free. The total amount spent on energy services is almost 40,000 ZMK (11 US$) for the clients, and 30,000 ZMK (8 US$) for neighbours (Table 2).While clients always have to pay at least ZMK 25,000 per month, neighbours are able to reduce their expenses if necessary (Fig. 3). NESCO notes that about 10–15% of their clients are in arrears in paying their service fees each month.

The fee is set on a yearly basis, and contracts between NESCO and the clients are renewed annually. Initially, the fee was ZMK 20,000, increased to 25,000 by 2001 and 30,000 in 2002 to account for inflation. Still, the value of the present fee is only about 92% of the ZMK 20,000 from the year 2000. This illustrates the problems of inflation.

Although the clients express concern about the expenses they have on the electric services, most of them (63%, $N = 68$) find the service fee reasonable. The clients to NESCO belong to what could best be described as a upper middle-class in the rural society. Most of them (75%) report that the household income is steady over the year. In addition, almost 90% of the households have one or more members with a formal employment.

3.2. Know-how

A SHSs' capacity is determined by the size of the panel and battery. For many of the clients who have no experience of electric installations in their houses, the introduction of a SHS becomes like having a grid connection. The problem is, however, that while grid connection provides a seemingly unlimited supply of power (not considering blackouts or disconnections), a solar system will only

[1] The exchange rate of 1 US$ was 3600 ZMK in June 2001.

Table 2
Expenses for energy services, median values. ZMK (USD)

	Electric services and light	Cooking fuel	Total
Clients	28,000 (7.7)	12,000 (3.3)	40,000 (11.0)
Neighbours	19,000 (5.3)	11,000 (2.9)	30,000 (8.2)

supply a limited amount of power. For the clients to operate the system efficiently, it is not enough to know how to switch on the lamps, but also to have a basic understanding of the capacity of the system. One of the clients reported that in the beginning they had watched the video until the power was cut. The result was that they could not use any light that evening, or the next morning. ''Now'', he said, ''we know that we have to be careful, or we will not have light''.

More than half of the clients (61%) reported that they had experienced problems with the systems. The main problem was that the system did not supply any power, called blackouts by the clients (55%) and the second most common problem was malfunction of the lamps (28%).

Blackouts are in most cases the result of over-use of the system in relation to available charging capacity. The main drawback of solar power is, according to 45% of the respondents, the low capacity of the systems. About 30% of the respondents do not think there are any drawbacks.

Users are not involved in any actual service or maintenance of the systems as this is taken care of by the technicians from NESCO. The clients are asked by the company to report any failures to the office so that they can be taken care of. The clients are not supposed to pay for the periods when there are technical problems with the systems.

A number of clients were reported to have connected inverters to the battery and by-passed the charge/discharge controller. This indicates that some clients' know how parts of the system works, and how to obtain additional benefits. For example

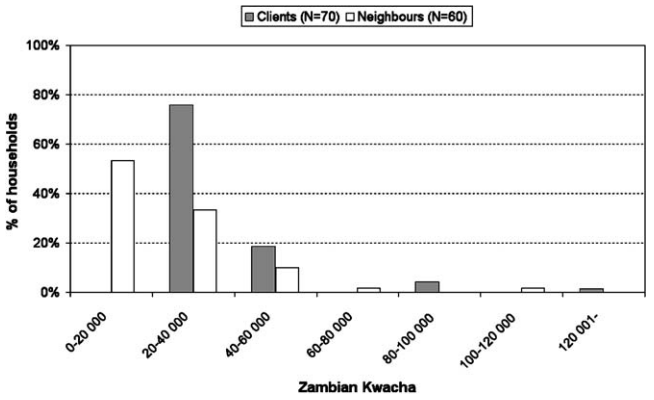

Fig. 3. Expenses on electric services and light NESCO clients and neighbours.

in other districts in Eastern Province, car batteries together with an inverter are often uses to run a television set. This is not very common in Nyimba, though, as there are no charging places in the town due to the lack of grid power.

3.3. Servicing and maintenance of the SHS

NESCO is taking the responsibility for servicing and maintenance, and the client only needs a very basic knowledge of how the system is to be operated. Technicians from NESCO visit each client on a monthly basis to check the system for malfunctions and carry out service. Monthly service includes to check acid level in battery, make a visual inspection of the system installations, clean the panel if necessary, and measure voltage over battery poles. A log is kept in each battery box and in addition, records are kept in the NESCO office.

The clients think this is working well. Despite this, 86% of the clients want to own the systems themselves rather than pay for the service from the ESCO. The main reason (50%) for this is that they wish to reduce the monthly expenses, but for many households (20%) they want to own the system so that they can bring it with them in case they are transferred to another location.

The battery and the lamps are the weak part of the system, while panels have worked without problems. Lamps have been reported to break after only few operating hours, and the lamp fittings have also broken. About 25–30% of the batteries have been replaced after only 2 years of operation. If the systems were operated a bit more carefully, it can be assumed that the batteries life span would increase.

3.4. Solar radiation

Solar radiation in Nyimba is around 5 kW h/m^2/day, and changes only slightly from season to season (Fig. 4). The level of solar radiation can be a problem during the rainy season, when the sky can be overcast for several days in a row.

About a third of the respondents reported blackout problems that they feel were of seasonal character. In the rainy season, battery may not be fully charged in one day. This might take a few days of charge from the panel, even without any load on the system. The battery will keep low charge, which causes frequent cuts and wears the battery down. If only lamps and smaller appliances are used for short periods of time, a fully charged battery can be used for 3–5 days.

Clients link the shaded sun and the loss of power. Their suggestion to increase the capacity of the systems is to have larger panels. No one mentioned the possibility to use more powerful batteries in order to store more power.

3.5. Benefits

A wide range of benefits can be obtained from PV technology and solar systems, apart from light, for instance, operation of radio and TV sets, communication equipment, water pumps, fans, etc. Almost 50% of the households stated that the children benefited most from the SHS. Half of the respondents stated that having light was the best thing with a SHS, and almost as many (43%) mentioned new

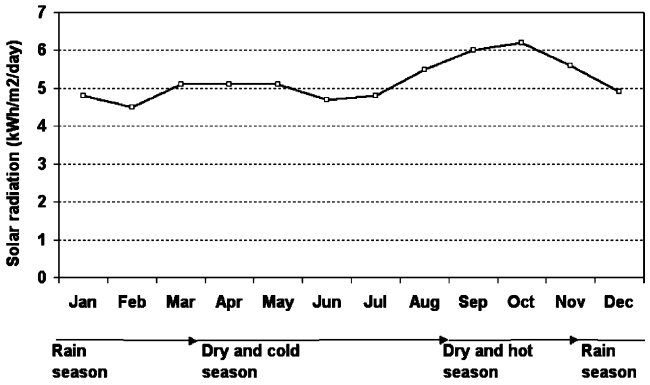

Fig. 4. Average monthly insolation levels in Nyimba district (data from University of Zambia).

possibilities for entertainment. The possibility to read and study at night (Table 3) was seen as the greatest benefit by about a third of the respondents.

The outputs from the technology creates new opportunities, but as a consequence also creates new daily routines and livelihoods. Two-thirds of the client respondents stated that they had changed their daily routines as a consequence of the access to electric services through the SHS. Three changes were specifically mentioned, of which two are related to access to more and higher quality light sources; do domestic work at night and reading/studying at night. The third is a result of the access to electric 12 V electric service; enjoy entertainment from radio or video at night. Reading and studying at night were not possible previously according to 58% of the respondents, and 47% had acquired new opportunities for entertainment (Table 4).

3.6. Light

There was surprisingly little difference between those with SHS (clients) and those with traditional lighting (neighbours) in terms of hours of light in the night. The median value for both groups was 3 h/day, average value for clients was 3.3 h/day and for the neighbours 3.1 h/day. Thus, it cannot be said that the result

Table 3
Best thing with solar electric services

Light	50%
Entertainment	43%
Study and reading at night	26%
Cheaper/saves money	16%
Improves living standard	7%
Other	4%
Children spends more time home	3%

The question was open-ended. Some gave more than one answer, making the total more than 100%.

Table 4
What a client can do that was not possible before having the SHS

Reading/studying at night	58%
Entertainment	47%
Business and working hours extended	16%
Cooking at night	16%
Using light at night	10%
Other	7%

shows a difference between light and darkness. Still, there is a difference in terms of quality of light. While a candle gives 1–16 lu, a kerosene wick lamp about 10–100 lu, compact fluorescent (solar lamp, 7 W) gives about 340–560 lu [18].

It can be expected that neighbours use their light sources more economically since, for them, there is a price per time unit. With the solar lamps there is no running cost of the lamps, but a monthly sum, independent of the use of the system. For example, a number of households kept a lamp on throughout the night as a security measure.

The improved quality in lighting is visible in the changes in study routines among children. In neighbour households with children in school age, 42% reported that the children were able to study at night, compared to 89% of the households with solar power. The most common source of reading light in the neighbouring households was candles (60%) followed by kerosene or paraffin lamps (30%). In about half of these cases, the respondents reported that the children complained about the light. These complaints were smearing eyes, lack of candles or paraffin and that the light was too dim to read in. Children in households with solar power study in the light of solar lamps. Only in 15% of the cases did these children complain about the light, and these complaints concerned blackouts, and in some cases restrictions in the use of the power.

Unexpected, but encouraging, results were reported from one village where children gathered in one of the houses with an SHS to study together in the light from a solar lamp. In this village, also children from households without an SHS were able to benefit from the solar power.

In some cases teachers having solar power in their homes have started to give night classes. This is an opportunity for the children without good internal light to get the same possibilities and opportunities as those living in more urban areas.

3.7. Electric services

Since lamps were included at system installation, it is obvious that the clients would have electric lamps. However, more than 90% of the clients had at least one electric appliance apart from the lamp. This can be contrasted to the neighbours where 75% had one or more electric appliances. Apart from the lamps in client households, radios and radio cassette players were the most common appliance (Table 5).

Table 5
Distribution of appliances among clients and neighbours

	Clients ($N = 69$) (%)	Neighbours ($N = 45$) (%)	Diff.
Lamp	97	7	+90
Radio cassette player	83	82	+1
TV	48	9	+39
Small radio	41	44	−3
Torch	39	76	−37
Video	38	2	+36
Fridge[a]	22	4	+18
Inverter	16	2	+14
Other	7	0	+7

[a] The fridges found cannot be used with the SHS since they are too power consuming. In most cases the households have brought these appliances when being transferred or moved from a place with grid electricity.

One major difference between the neighbours and the NESCO clients is ownership of a TV set. Neighbours do not own TV sets, while most have a radio cassette player at home (Fig. 5). In most cases, the investment in a TV set was made after the system was installed.

The possibility to operate a TV set is considered very attractive. For example, 50% of the neighbour respondents said that they would enjoy a TV and video more than a convenient stove or a water pump. A good stove was considered most important by 30% and a water pump most important by 20%. One side effect of the sudden access to television and music entertainment was that in some household the children are staying at home instead of running around in the neighbourhood.

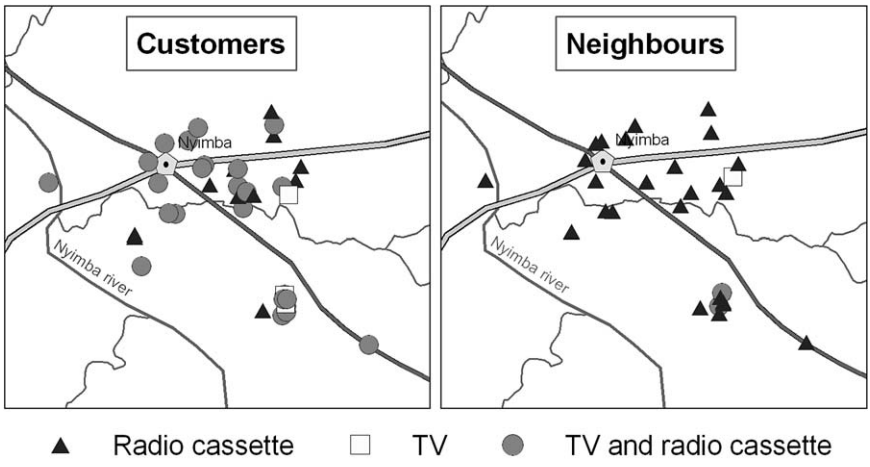

Fig. 5. Ownership of radio cassette players and TV sets.

Another example of the use of the power was in a secondary school, where the teachers were now able to arrange dances every week. Earlier there was always the problem to find money for the radio cassette player. Now, power is there, and the Parents and Teachers Association (PTA) pays the monthly fee to NESCO.

There is no possibility to receive the national TV or radio broadcast in Nyimba, so to watch televisions means to watch video. Hence, the project contributes to making Hollywood drama movies, Nigerian action movies and Indian music videos a part of the local livelihood. The media consumption becomes more global.

The limitations to the systems were noted by many clients. More than 40% of the clients made comments in the survey of the experienced low capacity of the system. However, to improve the capacity would require a panel with higher capacity as well as a larger battery. This would result in higher costs for the hardware and subsequently a higher monthly fee for the client. This was not elaborated on in the comments from the clients.

4. Discussion

The users of SHSs in the projects enjoy the services they obtain. The clients make up a well-to-do group in the rural setting and the company is not able to directly target poor people or low-income groups.

The solar system quickly becomes part of the daily life of the users, being integrated in their livelihoods. Daily routines change as a consequence and the clients experience an improvement of living conditions. One teacher in a remote area expressed this like "The lifestyle changes, it is like we moved from the rural area to the town. We now have light in the evenings and we can play the music."

The changes are a result of improved quality of energy services compared to traditional energy sources. For example, clients and neighbours keep almost the same hours of light in the evenings, but for the clients the light has a much higher luminance, which enables them to carry out activities that were difficult to do previously. Dry cell batteries are readily available in all areas where the study was carried out, but they are often of poor quality and do not last very long. Through the SHS, the quality of electric services has improved and people are able to receive higher quality energy services.

The technology implemented in the project functions well. There is, however, a need for know-how from the users side on how to operate the systems. This seems to have been underestimated by the ESCO, since many systems were used to a maximum without proper recharging of the batteries.

Not a single system has been stolen or vandalised during the now 3 years of operation of 100 solar systems. This can possibly be attributed to the close control that is kept of the systems in the client's houses, and the fact that they value the benefits of the systems highly.

The ESCO strategy has proved successful in that sense that maintenance, servicing and client contacts are found locally. The clients know the NESCO staff, and

when problems occur they know where to turn. Some clients brought this forward as a positive feature of NESCO.

During the time when the survey was carried out, the company was not required to pay for the hardware. The fee levels only covered the running costs of the company. The PV ESCO project will now implement a system for transfer of ownership. In order for NESCO to cope with repayments, they will need to increase the fee levels with about ZMK 20,000 per month, in order not to have to cut into current profit. This is an increase of about 70% from the level at the time of the survey. As a consequence, some clients will not be able to cope with the monthly fee and will have to terminate the contract. NESCO staff believe that small-scale farmers are those most likely to meet trouble with the increased fee levels.

5. Conclusion

The study shows that electricity services from solar energy installations are attractive to people in rural areas. This is in spite of the fact that clients to the project are actually paying more for energy services, than their neighbours without PV connection. Number of light hours in the houses is similar, but reason for people to spend more must be sought in the fact that solar electricity can provide higher quality services. The light provided is stronger and there are less complaints from children reading. The possibility to use a TV set with a video machine is a major attraction and difference to the previous situation, and is quickly incorporated in the local livelihood. Improved productivity was not strongly emphasised by the respondents.

The clients targeted are the better off in the rural setting. In most of the client households, one or more members have a formal monthly salary. Integration of the solar system in the livelihoods means improvements and new possibilities in the daily life, such as doing domestic work at night, reading and studying as well as watching video. For the rural areas, the access to solar power means getting possibilities that were previously only accessible for people in urban areas.

Acknowledgements

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