Practical approach for sustainable Solar Electrification of remote Rural Communities in eastern Africa: the case of Tanzania

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Abstract

Solar energy is one of the most important resources in the world, and advancements in solar energy technologies are making it more and more cost effective. Although the use of solar powered systems is rapidly increasing in many regions, the major barriers for wide spreads of such systems in remote rural areas of developing countries include lack of investment capital, cultural and technical barriers. This study was commissioned to assess the practicality of disseminating solar home lighting systems to remote rural villages in southern Tanzania, to identify specific barriers that may hinder adopting of such systems by wider communities in rural areas and recommend practical counteractive measures. The analysis used facts collected from key informants, focus group discussions and primary household-level data from 200 households in remote rural villages of Lindi and Mtwara regions. The study explored technical requirements, economic viability, and the policy and planning issues which may contribute to success or failure of an intervention. It was observed that the majority of respondents (80%) were enthusiastic towards acquiring solar kits for lighting their homes, especially those who happen to know these systems and were willing to pay between TAS 5000.00 ($3.3) and 10,000.00 ($ 6.6) as initial deposit to acquire a solar system,. In addition they were willing to pay TAS 5000 ($ 3.3) every month until the cost of the system is recovered. The payment is slightly lower than the cost they incur to buy kerosene and torch batteries for lighting. Despite, the willingness to acquire the lighting systems, it was observed that, success of such an intervention to large extent rely on availability of secure after sale services. The study could not identify any intentional government or other stakeholders' strategies or policy measure to ensure sustainability of such interventions. Investigation on similar projects implemented in other parts of the country revealed that, conventional methods of providing aftersales services have had little success especially when applied to remote rural areas. Therefore the study recommends training of local people especially women who are deep rooted in the village and are unlikely to migrate from their villages to urban areas. The training should cover installation, repair, maintenance and spare parts procurement. Since most of rural dwellers in Tanzania are semi-illiterate, special approach for selection of trainees and 'hands on' training should be adopted to ensure comprehension of the course content. Barefoot approach which has been used successfully to train such technicians and has proved to be a workable solution for provision of training on aftersales services in Northern part of the country is recommended for other rural communities.

Key words: *Solar home lighting kits, feasibility, Barefoot Approach, Tanzania*

1.0 Introduction

The Millennium Development Goals (MDGs), adopted at an international level in 2000, set a list of human development objectives to be achieved by 2015. The goals include eradicating extreme poverty and hunger, achieving universal primary education, empowering women, meeting basic minimum needs, reducing child mortality and diseases and improving maternal health. Although energy is not addressed directly in the eight MDGs, it is widely accepted that access to clean and affordable energy is a prerequisite to achieving sustainable development and reducing poverty. Energy is only one determinant of poverty and development, but it is a vital one. Energy supports the provision of basic needs (cooking, heating, lighting, etc.) and creates productive activities (manufacturing, industry, commerce, etc.).

The remoteness of the rural locations and the topography of the country side where most of the poor people lives make the expansion of conventional electricity supply through centralized grid system difficult, and may not be economically feasible. There is, therefore, an urgent need to explore alternative energy sources that can be maintained at a decentralized level and afforded by the poor. Solar energy technologies are considered the best alternative and have been demonstrated successfully in remote rural areas for basic services and production purposes. However, many of the projects delivering solar technologies to remote rural areas have not been sustainable due to lack of aftersales services which include spare parts supply, repair and maintenance services.

It is therefore fair to state that access to technologies using solar energy and their sustainability in remote rural areas in Tanzania and in Africa at large, is by far one of the most pressing challenge facing the continent, and should constitute an overwhelming concern for the accomplishment of any development goal including efforts for poverty reduction, health improvement, water provision, agricultural development, food security, etc. The rural area presents very specific challenges that are not fully taken into account by policy makers and energy sector managers. Until this is done, most solutions will fail to achieve their objectives in rural Africa.

This study identified the key factors which should be considered for the successful dissemination of solar energy technologies in remote rural areas. The study focuses on solar home lighting kits since availability of sufficient light contributes significantly to progress in education (Toor and Rizwana, 2004), health, and income generating activities that would result in poverty reduction. For sustainability of such a project, the study recommends the use of a model which ensures that the intervention is controlled and owned by the rural poor. The recommended approach which was tested in Northern part of the country, primarily calls for training of suitable local technicians and getting them involved in the setup and maintenance process. This attitude overcomes dependence on urban technician who are expensive to hire and in most cases are not available when needed.

2.0 Materials and methods

2.1 The Study area

The study was conducted in seven villages in Kitere and Nitekela wards, Mtwara rural district and in Chikonje and Kitomanga wards, Lindi rural District. The villages namely Lilido, Chekeleni, Nitekela and Niyumba, represented typical villages in Mtwara region, while Lindi region was represented by Kitomanga, Chikonje and Nanyaje villages. The Study area which lies between latitudes 7.55° – 10.5°S, and longitudes 41° – 38.8° E is sparsely populated with average population density of 56 per km² and an annual population growth rate of 1.4 per cent (URT, 2004). The main source of income is agriculture which contributes about 75% of the total income. Other activities include fishing, petty businesses and small industries.

2.2 Data collection and Analysis

In collecting information the study involved both quantitative and qualitative approaches. Key informants, including, District Executive Directors (DEDs), Community Development Officers (CDOs), ward and village leaders were interviewed to obtain preliminary information on energy use pattern, socio-economic aspects of the community and their contribution to household livelihood. The information was used for selection of the villages to be sampled for detailed study.

The detailed study was conducted through as semi-structured questionnaire, which aimed at identifying the challenges posed by local circumstances in relation to energy used for domestic purposes. The interviews paid special attention to the contribution of the energy use practices to household income, healthy, environmental degradation and climate change. Secondly, focus group discussions were used to cross check some of the information collected during interviews and to capture information that could not be collected during the household survey. Focus group discussions, led to identification of target group's energy and technology needs, attitude and preferences of respondents towards solar electrification and their willingness to pay for the cleaner energy source.

3.0 Results and Discussion

3.1 Households Socio-economic characteristics

Half of the respondents were aged more than 45 years and very few (6%) were aged below 24 years. Sixty six percent were literate with 7 years of primary education. Only 2% had secondary school education while 11% had adult education. Those who had not gone to school were 21%. The average family size in the villages studied was about 5 people. When household members were divided into age groups, the largest age group was that of less than five years and the smallest was that of more than sixty year of age. The main occupation of the villagers in the study area is agriculture (96%) with few people employed by the government (3%) and some doing petty business (1%). The main types of crops grown are cashew (80%), maize (52%), cassava (90%), millet (35%), rice (18%) and ground nuts (25%). Most of the households (58%) keep an average of 9 chickens while very few keep other types of livestock (7%). The main source of household income (96%) in the district is through sales of agricultural produce which include sale of cash crops and surplus food crops. The major agricultural crop grown for cash in this area is cashew. Due to dwindling returns from cashew, other crops like sesame and cassava are being grown intensively as an alternative source of income. The average per capita income is TShs 160,030 ($106.7) implying that most of residents earn less than half a dollar per day.

3.2 Housing and Household assets

Most families had one house (98%) with two to four rooms which are used for sleeping, cooking and storage. The wall materials used for construction were wooden poles alone (21%); wooden poles and mud (67%) and concrete block or burnt bricks (11%). In most cases roofing materials used were grass thatch (78%) and iron sheets (22%) while the floor materials were earth (94%) and concrete (6%). About 47% of the houses were poorly constructed with meagerly thatched roofs, inadequately wall finish (i.e no internal doors, no windows and no roof sealing materials). Only 1% of the houses were outstandingly constructed. Other assets owned by the respondents include farming tools (91%), motor cycles (3%), bicycles (20%), radios (68%), televisions (3%), lamps (68%) and cell phones (5%).

3.3 Lighting Energy

The most common energy source for lighting was kerosene (63%), followed by torch (39%), open fire (19%) and candles (7%). Each household uses about 100 mls every day which is equivalent to 36 litres per year which result into emission of 24.6 kg of carbon dioxide per household. The average cost per 50mls (koroboi) of kerosene was TAS 150 ($0.1). A litre of kerosene is sold around TAS 3000 ($2). Most families had one locally made *tin can* lamp while they have an average of 2-3 rooms which requires lights during the night. The *tin can* lamp is used for providing light at the cooking place. In addition, about 30% of the families go without reliable light for about 15 days per month because cannot afford to pay $0.1 per day for kerosene. Among the poorest of the poor, lighting is one of their largest household expenses, typically accounting for 10-15% of total household income. Kerosene lamps provide low quality and very expensive light. They introduce multiple health and environmental hazards, as well as a significant fire risk.

Kerosene is very polluting, causes indoor air pollution enough to cause severe respiratory problems for children in enclosed village huts, and pose a fire hazard. Kerosene lanterns emit 1/3rd of a ton of carbon dioxide every year, and the total emissions in villages are significant as about 30 million people use them. In addition to health risks, kerosene creates a dangerous fire hazard. Kerosene and candles cause countless fire catastrophes every year. In 1998, there were 282,000 deaths from fire related burns worldwide and 96% of the fatalities were in developing countries (.Barki and Barki, undated). Each year, many homes and even entire communities burn to the ground when a lamp is toppled.

The light provided by a *tin can* kerosene lamp is not very bright. The light is only 2 to 4 lumens compared to a 60 watt bulb with 900 lumens (Tanzsolar, 2010). The amount of light from the lamp is only about 0.2% of what the people in industrialized countries have for the same price. The light is so poor that children can only see their books if they are almost directly over the flame. Parents and children can only practice very basic reading and writing skills after dark when they are dependent the inconsistent and poor light provided by kerosene wick lamps and wood fires. Kerosene lamps and improper lighting create a barrier to education and learning.

3.4 Attitude and preferences towards modern sources of energy

On average, 93% of the respondents were not satisfied with using kerosene and wood fire for lighting. Reasons advanced for the discontent include: (i) Scarcity of fuel wood during rainy season, (ii) collection of fuel wood time consuming and cumbersome; (iii) wood fuel, candles and kerosene cause indoor air pollution leading to eye irritations, coughs, and bronchitis; (iv) upon combustion, kerosene yields carbon monoxide and carbon dioxide which contributes to greenhouse effect. The respondents were enthusiastic towards acquisition of solar electricity for lighting their homes, especially those who happen to know these systems. While 85% of the respondents know or have heard about solar energy, only 80% of preferred solar energy systems over other forms of renewable energy technologies, the remaining 20% were not sure of the benefits of solar energy. Awareness on other forms of feasible renewable technologies such as biogas and wind power was very limited.

The majority of respondents were willing to pay between TAS 5000.00 ($ 3.3) and 10,000.00($6.6) as initial deposit to acquire a solar system; thereafter they were willing to pay an agreed amount of money until the cost of the system is recovered. About 30% of the respondents were willing to pay over TAS 8, 000 ($5.3) per month, which is equivalent to the cost they pay to use kerosene and torch batteries and 60% said could only afford to pay between TAS 5000 ($3.3) and the rest could afford 3000 ($2.0). Collective decision by the community was to pay $3.3 per month as installment for recovery of purchase costs. Since solar lighting products that are available in the market cost approximately $200, loan period will have to be about 5 years. The solar lights offset the need for kerosene lanterns and the money saved on kerosene will be much equivalent to the monthly installment.

However, the greatest challenge of solar electrification of rural remote villages is not the ability of the villagers to pay for the needed accessories (at least on installments); there is a plethora of factors inhibiting the rapid development of solar home systems. Factors identified by this study were similar to those pointed out by Pode (2010) in Northern part of the country. Table 1 summarizes the key factors hindering adoption of solar home lighting kits by remote rural communities in Tanzania.

Table 1: Barriers to adoption of solar technology in Tanzania

Barriers	Degree of importance	Methodology for redress issues
Inadequate business knowledge and capacity for distribution	Major barrier	Build business knowledge and capacity for distribution of solar PV systems
Limited technical knowledge of sizing, installation, operation and maintenance.	Major Barrier	Training selected community member to size, install and repair solar
High cost of solar systems, initial capital investment and operation and maintenance	Major Barrier	Introduce credit scheme. Repayment of the load should correspond closely to the amount of money served from using kerosene, candles and torches
Low purchasing power of rural people	Major Barrier	Subsidize promotion of solar technology
Limited awareness of and experience with PV technology	Secondary Barrier	Increase Understanding of solar PV technology to the large community via media and personal networking
Lack of established dealer network	Secondary Barrier	Build a network of dealer
Inadequate policy implementation	Secondary Barrier	Formulate/revise policies to support solar PV
Difficult access to finance for end users	Secondary Barrier	Formulate micro credit scheme

These barriers can the summarized in three categories which include, investment barriers, technical barriers: and 0ther barriers.

3.5 Overcoming the barriers to solar electrification of remote rural villages

A large number of energy service delivery initiatives aimed at the poor implemented across Africa and elsewhere in the world have had little success because the rural area presents very specific challenges that are not fully taken into account by policy makers and energy sector managers. Until this is done, most solutions will fail to achieve their objectives in rural Africa. The reasons for the failure of many energy initiatives may be traced to flawed approaches to dissemination, typically the top-down approach to planning and implementation of projects, resulting in failure to address the needs of the intended beneficiaries (Mapako and Musvoto, 2008). Many approaches that experts have taken to reach the poor have been patronizing, top-down, insensitive, and expensive. It excludes the marginalized, the exploited, and the very poor and keeps them from making their own decisions. Thus it dis-empowers them, leaving them dependent and hopelessly ill prepared to improve their lives.

As an alternative decentralized and demystified energy delivery approach is gaining significant attention. Decentralized solar lighting systems are attractive because they can target a particular energy need, be mobilized relatively quickly, are modular in nature allowing for expansion or reduction based on need and economic means, can be individually or communally obtained and are environmentally sound at both the local and global level. Of greater importance is the fact that decentralized systems keep the energy system close to the end user, allowing the end user’s direct control of acquisition, design, placement and consumption decisions. This is especially relevant to remote rural villages where convention energy distribution and transmission systems are either not economical or feasible.

While the decentralized paradigm of solar lighting delivery is gaining favour in rural areas of developing countries, the successful implementation of such systems requires a keen understanding of local energy needs and preferences, sensitivity to the local cultural and economic realities, and an understanding of the technology. Overcoming rural solar electrification barriers starts with demystification of the technology i.e. giving the poor the right to decide for themselves if they want to use the technology to improve their quality of life. They must have the right to choose whether they want the urban experts to come into their villages with "modern" ideas. They can even decide whether some knowledge would be useful if they could adapt it to serve their needs. What they need is the opportunity and space to develop them. When provided with that mental and physical space, the poor can achieve wonders without any outside professional interference or advice.

Bunker Roy (2008) through the Barefoot College has been pioneering such an approach, which gives the responsibility to choose and apply and adapt technology to rural communities. Barefoot College has demonstrated the enduring value of a process and system that is totally owned by the actual beneficiaries. The ideas have helped lift the marginalized communities out of poverty and given them tremendous hope. By bringing the value of community knowledge and skills into mainstream thinking in modern technology, engineering, and architecture, Barefoot College has revealed the relevance of development that is sustainable, community owned and community managed. They have demonstrated the people cannot be developed but they develop themselves. This study recommends application of barefoot approach to disseminate solar lighting systems to remote rural villages in southern Tanzania.

3.6 The Barefoot Approach

The Barefoot Approach has been used to reach remote, poor, rural villages in 25 countries in Africa, Asia and Latin America. Illiterate rural women who are not likely to relocate from the remote villages to relatively urban areas are given a six months hands-on training on installation, repair and maintenance of solar lighting kits. After training the women return to their villages as solar technicians. The approach has proved that the very poor and illiterate villagers can control, manage and own sophisticated technologies to improve their own lives. Just because they didn't get formal education, there is no reason that very poor women cannot be water and solar technicians, designers, communicators, midwives, architects and rural social entrepreneurs. Through the barefoot approach more than 140 rural women have solar electrified 9,118 remote rural houses in 21 African countries. It is an extraordinary story because illiterate women are considered un-trainable in rural African society and after their training they have become role models for their communities. As a result of solar electrifying their communities, they have managed to save more than 30,000 liters of kerosene per month from polluting the atmosphere all over Africa.

3.7 Sustaining solar home lighting project using Barefoot Approach

The barefoot approach was designed to demonstrate technically and financially self-sufficient, solar electrified rural villages in Afghanistan, Bhutan and Africa. The target community has been the rural poor families living on less than $1 per day where the women spend hours fetching wood or kerosene, or rely on candles and flashlight batteries for lighting at very high costs. After food, the highest family expenditure in such communities is on lighting. By training illiterate rural women to be competent solar technicians, there is no need for urban solar engineers to supervise the installations and provide after sale services in rural areas. The approach eliminates the dependency of rural communities on urban experts.

The approach encourages the communities to pay every month for the use of the solar units (normally equivalent to what they would have spent on kerosene, candle and orches); through the monthly collection, the financial commitment is assured for the purchase of replacement components and for paying monthly salary of the village solar technician. This salary provides the incentive for the technician to work and look after the units regularly or she will not receive her monthly salary. Each household agrees to pay a fee between $2 to $10 a month for the solar lighting, roughly what they used to spend on kerosene, candles and flashlight batteries. The barefoot approach leverages local community contribution and participation with public and private sector investment and financing. Working in partnership with the local community, the Barefoot Approach draws on a mix of resources including government and international funding agencies, private foundations, and corporate and individual sponsors to enable the appropriate investment for cost-effective and self-sustaining solutions for delivering solar power in poor, rural communities.

The approach effectively demonstrated that a combination of traditional knowledge (barefoot) and demystified modern skills can bring lasting impact and fundamental change when the tools are in the control and ownership of the rural poor. Many initiatives providing solar-powered lighting in remote villages are implementing a top-down approach where the installation is done by engineers coming from cities with no idea how to work and communicate with poor communities. Their faith in the capacity and competence of the rural poor to fabricate, install and maintain the solar units is totally absent. However, the primary obstacles that are coming in the way of the demystified approaches like Barefoot Approach is the dogmatic mind set of expert and the failure for the learned to comprehend and understand that an illiterate rural woman who has never been to school or college can be a solar technician. Few believe that sophisticated 21st century technology like solar should be or could be managed, controlled and owned by very poor rural women earning less than $1 a day. It is by taking whole communities into confidence and making them take all the decisions that wastage can be minimized, urban migration reversed, and pilferage and theft of solar panels in villages eliminated. That is why a change in work style and mindset is required to provide clean, inexpensive, pollution-free light to the poor around the world.

3.8 Success of barefoot approach in Tanzania

Dena (2010) used the Social Returns on Investment (SROI) approach to assess benefits of solar lighting beyond conventional cost-benefit analysis, in two villages in Northern Tanzania which were electrified using the Barefoot Approach. In addition to many positive finding,the author concluded that the Barefoot Approach provided remote communities in Northern Tanzania with solar lighting and in the process; communities gained economic, health and social benefits. By empowering women to take on technically challenging and important roles, project encouraged an increase in social equity. Through SROI approach, it was revealed that the implementation of solar lighting has benefits which go far beyond an increase in income or savings; solar lighting contribute to a decrease in environmental degradation by reducing the harmful emissions given off by kerosene lanterns, create healthier indoor environments, facilitate evening communication and social events, thus increasing community and family cohesion, provide children with more time for their studies, thus helping them to achieve their potential, and they provide community members which opportunities for entrepreneurship (ex. Poultry business, cell phone charging business, etc.). These benefits collectively enhance the quality of life in beneficiary rural villages.

4.0 Conclusion and recommendations

- Solar electricity is a feasible solution to rural electrification especially for lighting. Solar lighting systems are in many cases economically superior to conventional power systems because of the operating costs are low and long working life. Solar home lighting systems are virtually maintenance-free, requires few spare parts, and no fuel is needed.
- High-efficiency solar lighting systems not only provide superior light over fossil fuel based lighting, but are also less expensive if costs are spread over their entire life cycle. By providing clean, adequate indoor lighting, the general living standard of people living in deep poverty can be greatly improved.
- By displacing the traditional '*tin can'* kerosene lamps, solar systems have the potential of reducing the rate of deforestation and CO_2 emissions. The current trend in design of solar lighting systems suggests such systems will be more efficient and cost effective in the near future.
- Success of solar home lighting kits in remote rural villages depend primarily on training of suitable local technicians and getting them involved in the setup and maintenance process. This attitude overcomes dependence on urban technician who are expensive to hire and in most cases are not available when needed.
- The study recommends training of local people especially women who are deep rooted in the village and are unlikely to migrate from their villages to urban areas. The training should cover installation, repair, maintenance and spare parts procurement. Since most of rural dwellers in Tanzania are semi-illiterate, special approach for selection of trainees and 'hands on' training should be adopted to ensure comprehension of the course content.
- Barefoot approach which has been used successfully to train such technicians and has proved to be a workable solution for provision of training on aftersales service in Northern part of the country and is recommended for other rural communities

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