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Addressing Barriers to Off-Grid Rural Electrification in Africa: The Botswana and Namibia Experience

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Abstract: Africa is the most affected continent with energy poverty. Wood fuel is the main source of energy for remote and rural populations. At the same time, most parts of Africa are endowed with abundant solar energy. Together with a highly developed global solar industry and ever declining cost of solar systems, solar has unprecedented potential to combat energy poverty in Africa. However, dissemination of solar systems is faced with a number of barriers and challenges amongst where sustainable financing and lack of technological support for installation, maintenance and repair of systems are the most significant. This paper discusses the cases of Botswana and Namibia where financing schemes based on different partnership models have been successfully implemented. These schemes have the potential for success and adaptation by countries with similar socio-economic conditions. We conclude with recommendations on training programs for different levels of intervention to overcome the lack of technological support.

Key words: Energy poverty, off-grid rural electrification, solar energy, financing mechanisms, training needs, Africa, Botswana, Namibia.

1. Introduction

Energy poverty is the mother of all poverties. Lack of access to sustainable and affordable energy to rural and remote communities in developing countries, amongst others, is linked to:

- lack of job and self employment opportunities;
- lack of teachers and facilities in rural schools contributing to poor educational standards;
- inadequate health care because of the lack of facilities and unwillingness of qualified health professionals to work in rural clinics and health posts;
- large scale rural to urban migration of young and able-bodied people in search of employment, leaving behind the old, the sick, and the children to fend for themselves.

These perpetuate the cycle of poverty which can be broken by injecting sustainable and appropriate energy sources in the rural communities to bring about social and economic development [1].

Africa is the most affected continent with energy poverty. Energy supply and consumption in rural Africa is characterized, on one hand by the use of wood fuel as the main source of energy with associated environmental consequences, and lack of infrastructure for the supply of commercial energy sources on the other [1].

Variety of approaches involving both grid and off-grid electrification have been used to meet the energy needs of rural and remote populations in different countries and regions. Nevertheless, the problem of rural energy supply is a complex one, and it is further compounded by the lack of financial means and material resources.

With sparsely populated and vastly separated villages scattered across most of the African countries,

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grid-based rural electrification is a cost intensive undertaking, and this has been the major barrier. Besides, there are also a number of other challenges faced as illustrated in the examples below [2]:

- When grid power is extended to a new village, only some of the households (below 40% in some cases) are able to connect to the grid, and most of those connected continue to use gas, wood and other fuels for cooking and heating due to the high cost of electricity and the electrical appliances. Use of electricity is restricted to lighting, music, radio, TV, fans and small/affordable kitchen appliances.
- Rural communities have very low electricity consumption represented by low power applications listed above but they still demand same services as those offered in urban centers with high consumption rate. Thus, it is not cost effective for power companies to provide grid electricity to consumers with such a low rate of power consumption.
- When more villages are taken on board for grid connection they are found to be even less financially viable than those to whom the services had been extended earlier because the later ones rank lower in priority because of their smaller population or remoteness or both. This compounds the financial woes of rural electrification.

In most cases, therefore, grid-power is not the best viable option. One alternative then is to deploy the off-grid systems using renewable energy resources, such as solar, wind, biogas, geothermal, mini hydro, etc.. Our focus here is on the use of solar energy in a region which has sunny skies for most of the year [3].

2. Why Solar?

Solar radiation is the only and most abundant renewable energy source distributed throughout the world reaching even the remotest and most inaccessible corners of earth. According to one study [4], if only 7% of the total area of six of the deserts of the world is covered with 8% efficient solar PV devices, they will produce 18 TW electrical power which is more than the total power currently available from all the primary energy sources, including coal, oil, gas, nuclear and hydro. This renders solar energy as the most viable and sustainable energy option in remote and rural areas, where the availability of other sources of energy is lacking. Countries of Africa are no exception to this.

In most African countries, a large percentage of the population lives in rural, remote areas, sometimes not easily reachable. Delivery of commercial energy sources to such areas remains a big challenge because of inadequate, more often non-existent distribution infrastructure, low rate of consumption and low revenue generation potential. At the same time, solar radiation conditions for the most part of Africa range from good to excellent [3].

3. Challenges of Rural PV (Photovoltaic) Electrification

Despite its vast potential, solar energy has not been able to contribute significantly to the global energy consumption. The foremost reason is the high cost of solar devices and systems which compare unfavorably with the cost of fossil fuel based energy options. Likewise, off-grid solar PV electrification of the remote rural areas in Africa has also not progressed well. The biggest challenge is the unsustainable financing mechanisms [2]. The rural consumers are generally too poor to outright invest in such high-cost products. Often they do not even have adequate assets against which a loan could be raised. Repair and maintenance of the systems is the second major constraint because of the lack of trained technical manpower and the high cost and the time it takes for a technician from the nearest service centre to attend to the problem. Lack of training also leads to inappropriate choice of systems and devices [5-7].

Republic of Botswana and the Republic of Namibia, in Southern Africa, have implemented two distinctly different financing schemes. Botswana has adopted the fee-for-service model, while Namibia has entered

into the Public Private Partnership for loan schemes at subsidized interest rate. We present case studies of these two financing mechanisms from Botswana and Namibia so that other countries in Africa can opt for one or the other scheme which suits their socio-economic scenarios.

Maintenance and repair of the systems is built into both the financing models. Essential training programs for long term sustainability are also discussed. We also briefly review how the PV electrification programs in Botswana have evolved over the past three decades [2]. Lessons learnt from it can be of paramount importance for countries that are yet to embark on the solar route.

4. History of PV Electrification in Botswana

Events listed below in chronological order are identified as the important land marks in rural PV electrification initiatives in Botswana [2].

(1) Solar PV electrification in Botswana was started in the early 1980s under the BRET (Botswana Renewable Energy Technology) project. The BRET project provided electrification in some rural clinics, primary schools, and the BNLS (Botswana National Library Services) rural reading rooms.

(2) In 1990, the Government of Botswana mounted an awareness campaign to promote solar energy through radio programs, Kgotla (community) and council meetings, and other public rallies. Two pilot projects based on two different models of PV electrification were commissioned to assess technical and financial feasibility, reliability, and viability of solar energy usage. These were the Manyana Pilot Project of stand alone domestic solar systems and the Motshegaletau centralised PV power station for power generation and distribution through a local grid.

• Manyana Pilot Project was started in 1992 at the Manyana village with a population of about 2,500 km and 50 km southwest of the capital city, Gaborone. PV-lighting in 42 houses, and 7 street lights were installed at government cost. SWH (solar water heaters) were installed in the residences of some of the primary school teachers. The project was evaluated after four years (1996), and recommendations were made to undertake similar project countrywide. At the end of the project, the domestic systems were transferred to the users at an affordable cost taking into account their depreciation over four years except for two systems which were repossessed. Street lights were transferred to the district council.

• The BOTEC (Botswana Technology Centre) constructed a centralised PV power station with a peak capacity of 5.7 kW at the Motshegaletau village to study the viability of centralized PV power generation and distribution in Botswana. The power station went into operation in 1998. Power was supplied at 220 V AC through a local mini grid to 14 households, the village clinic, a local bar, the primary school, and street lights. Consumers paid only for the consumption of electricity. In July 2007, when power from the national power grid reached the village, the PV power station was decommissioned.

(3) Following the success of the Manyana Project, off-grid solar PV systems were included in the BEMP (Botswana Energy Master Plan) in 1996 to ensure universal access to basic energy services for lighting, and solar thermal systems for cooking and heating.

(4) In 1997, the NREP (National PV Rural Electrification Program) was launched with three main objectives:

• to undertake rural electrification through the use of PV system where provision of power from the grid was not economically feasible;

• to make PV systems affordable to rural populations through sustainable financing schemes;

• to diversify the energy-mix in Botswana by including renewable energies.

(5) The RIIC (Rural Industries Innovation Centre), Kanya was charged with the implementation of the program under the guidance of the EAD (energy affairs division) in the MMEWR (Ministry of Minerals, Energy and Water Resources). Domestic PV

systems were installed on down payment of 15% of the cost. The balance was payable in four years at the prime rate of interest at the nearest post office. 300 systems had been installed up to 2,000. The program has since been overtaken by other developments.

(6) In 2000, the GoB (Government of Botswana) represented by EAD, MMEWR and the Japanese government represented by the JICA (Japanese International Cooperation Agency) entered into an agreement to conduct a three year master plan study on Photovoltaic rural electrification in the Republic of Botswana. Three villages were selected for the study. In each village one hundred PV solar systems of 50 W capacity each were installed in homes, small businesses, clinics, schools. A PV powered battery charging station was also established in one of the villages. Fee-for-service model was adopted to cover the maintenance and overhead costs under which users only made a single monthly payment. The on going current rural PV electrification program emerged from the experience gained and lessons learned from this project.

5. Financing Rural PV Electrification in Botswana

The ongoing current rural PV electrification and financing of solar systems has been undertaken in two phases.

5.1 Phase 1: The Pilot Program Stage

Pursuant to the recommendation of the master plan study on Photovoltaic rural electrification in the Republic of Botswana, the Government of Botswana and the GEF (global environment facility) of the UNDP (United Nation Development Program) signed an agreement in October 2005 to undertake RE (renewable energy) based rural electrification program (RE Botswana) for a period of five years with a completion date of October 2010. The government provided a funding of BWP (Botswana Pula) 19 million (US$3,636,463), and BWP 15 million (US $3,000,000) was provided by GEF. The BPC (Botswana Power Corporation) was responsible for the implementation of the program. In addition to rural PV electrification, efficient consumption of wood and fossil fuel for cooking and water heating was also targeted in order to reduce carbon emission and to conserve wood resource. The following products and services were offered either on fee-for-service terms or on sale.

- Solar PV systems for domestic lighting and low power appliances such as radio, telephone, cellphone charging, television, small refrigerator, computer, light tools and home security system were offered on payment of an initial installation charge and thereafter a monthly rental charge for the service. Consumers did not pay to own the systems.
- Rechargeable lanterns and batteries were offered on sale.
- Charging stations were established to charge for a fee there chargeable products and appliances including cellphones.
- RE Botswana was to construct a solar PV based mini grid to provide power to households, Government institutions, and small businesses in selected areas.
- Efficient cooking stoves using wood or coal to reduce fuel consumption, conserve the environment, and reduce health hazard from smoke were sold.
- Maintenance of the existing solar PV systems was included in the RE Botswana Program.
- RE Botswana was also to develop sustainable financing and delivery mechanism for large scale, long term dissemination of PV-solar products and services to rural and remote communities in the country.

5.2 Phase 2: The Current Ongoing Program

In the following sections, in order to maintain local and regional relevance, we have used currencies of Botswana and Namibia for local costs and pricing. The indicative currency exchange rates given in Table 1 can be used by international readers for estimates in the US$.

Table 1 Indicative currency exchange rates.

1 Botswana Pula (BWP or P) ~ 1 Namibian $ (N $)~ 1 South African Rand (ZAR or R)
1 US $ ≈ 8.5 BWP ≈ 8.5 N $ ≈ 8.5 ZAR

As the RE Botswana program (phase 1) approached the end of its tenure, a joint venture company, BPC Lesedi (Pty) Ltd. (Lesedi stands for light in Setswana, the native language of Botswana) was formed in 2009 to roll out PV solar products and services. BPC Lesedi company is limited by shares, owned jointly by BPC having 55% shareholding and EDF (electricite de France) international (South Africa) holding 45% shares, EDF—the French utility company). Managed by a board of directors, the company provides RE products and services for sale, on rental, and on fee-for-service basis through franchised outlets. It is planned to have 100 to 130 franchisees across the country, and regional offices shall serve as warehouses for the franchisees. 40,000 customers are projected to be reached in ten years. Products and services presently offered by BPC Lesedi franchisees are:

(1) solar electric system (Fig. 1):

• It consists of a PV panel, a charge controller, and a 100 Ah gel battery;

• Battery life is estimated at four years, and will be replaced free of cost when necessary;

• It is available in three load sizes, excluding appliances, to power:

- 4 lights + radio;
- 5 lights + radio + 54 cm colour TV, and;
- 7 lights + radio + 72 cm colour TV + small refrigerator;

• It is available on payment of an initial fixed fee for installation, and a monthly fee-for-service charge. For the 4 lights system, initial payment is BWP700/=. The monthly charge of BWP70/= can be paid at the nearest post office.

(2) rechargeable lantern (Fig. 2):

• It is a LED lantern with a 4 Ah SLA (sealed lead acid) battery;

Fig. 1 PV panels of typical solar system for domestic use in rural homes of Africa.

Fig. 2 A rechargeable LED lantern for rural and domestic use.

• 50 hours of light is provided from full charge;

• Can be purchased at BWP185/= per lantern or rented;

• Recharging is done at a charging station for a fee;

• Charging fee is BWP5/= per charge, or BWP20/= per month for an unlimited number of charging.

(3) rechargeable batteries:

• These are suitable for radios, audio cassettes, CD players, and flash lights;

• These are good for 200 recharge cycles;

• Can be recharged at a charging station for a fee;

• Can be purchased at franchise outlets. Cost, starting at BWP67/= per battery, varies with the size and model.

(4) charging station:

• These are fully equipped and rented out to the franchisees in every village.

• equipment consists:

- one 80 Wp power PV solar module;
- one 100 Ah battery, and;
- 20 DC charging outlets.

(5) efficient wood stove (Fig. 3):

- These are made from metal and ceramic;
- Heat loses are reduced, and food cooks faster;
- Reduces wood consumption by 60%;
- Reduces smoke and related health hazard;
- Priced at BWP90/= each, are available at franchise outlets.

(6) hot bag (Fig. 4):

- Keeps food/water warm;
- Certain half cooked foods, like rice, can complete cooking in the bag;
- Saves up to 40% wood as there is no need for re-warming of food/water;
- Priced at BWP300/= to BWP500/= depending on the size, they are sold at franchise outlets.

5.3 Other Planed and Ongoing RE Projects in Botswana

A number of other medium to long term competed, in progress and in the planning stage RE projects in Botswana include:

- A 1.3 MW grid interactive PV power plant at Phaklane, 15 km outside Gaborone, with finance from the Japanese government under the cool earth partnership was completed in August 2012 and has been in operation since.
- A bankable feasibility study is undertaken on a 200 MW grid interactive concentrated solar thermal power station. At present, BPC is the government owned only power utility in the country. The Amended Act 1 of 2007 allows for IPPs (independent power producers), and plans are underway to set up independent energy and water regulatory body.
- Feed-in tariffs from renewable sources of energy from private producers are being considered.
- The National Energy Policy stipulates 25% of the demand to be met through renewable energy by 2030 as compared to less than 1% at present. Despite the large potential market for renewable energy in the country, implementation of solar and wind systems is still limited to small-scale domestic and institutional applications.

Fig. 3 A stove for efficient combustion of wood/coal for cooking/heating.

Fig. 4 A hot bag to keep food/water warm to conserve energy.

- The major ownership of solar power projects for grid connected PV systems shall lie with BPC. Systems of over 25 kW are envisaged to supply communities, villages or institutions.
- Biofuels: MMEWR will be undertaking a five year Jatropha research project in collaboration with the Nara Institute of Science and Technology, Japan. This study is an information based optimisation of Jatropha biomass energy production in the frost and drought prone regions around Kaglagadi desert in Botswana.
- Only other feasible RE for Botswana could be the bio-gas because of a large cattle population. Feasibility study to electrify a small village close to a borehole where large numbers of cattle are watered has been completed. Implementation, subject to the availability of funds, is pending.

6. Financing of Solar Systems in Namibia through Public Private Partnership

In 2003, Namibian MME (Ministry Of Mines And Energy) with support from the UNDP (United Nations

development program) and the GEF (global environment facility) started a project on barrier removal to NAMREP (Namibian renewable energy programs). Lack of financing, particularly in rural areas, was identified as one of the barriers to increased deployment of solar energy systems. In order to address this problem, PPP (public private partnership) between BW (bank Windhoek), a commercial bank, and the MME through the NAMREP was mooted and negotiated. The Bank was to provide loans for solar systems at a reduced interest rate under limited guarantee from NAMREP [8]. The dynamics of the scheme was as follows:

- In 2005, MME entered into a MoU (memorandum of understanding) with the BW to finance at an affordable interest rate SMEs (small and medium enterprises) to set up businesses in SETs (solar energy technologies) in rural areas, and to finance individuals to install SETs. Limited guarantee by MME through NAMREP against default in both cases was provided.
- The loan limit for NAMREP approved SMEs was set at N$20,000 to N$250,000 at an interest rate of 3% less than the Prime rate of interest with 70% guarantee from MME.
- The individual loan limit was set at N$20,000 for a solar home system and N$40,000 for a solar water pump at an interest rate of 5% below the Prime rate of interest with 80% guarantee from MME.
- The loan guarantee was provided via an investment opened at BW at 0 rate of interest. The income earned from the investment was used to subsidise the rate of interest below the prime rate of interest for the loans.

6.1 Implementation and Outcomes

- The scheme was launched in 2006.
- Initially NAMREP put in N$4,000,000 as loan guarantee sum. Soon afterwards, the Bank added N$4,500,000 of their own funds to the scheme.
- With the total sum of N$8,500,000 loans were granted to six entrepreneurs, and 208 individual consumers which included 157 solar home systems, 44 solar water pumps and the rest SWHs (solar water heaters). The rate of interest on the loans ranged from 8.25% to 10.25%.
- There has been only about 2% rate of default on loan repayment, and no loans have been written off, although a provision of N$60,000 had been made for this in the scheme.
- Following the success of the scheme, two other banks, the Standard Bank and the First National Bank launched similar loan schemes for SWHs for home owners. They also included the cost of SWHs in their home loan schemes which was not the case earlier.
- There have been two problems with the implementation of the PPP scheme :

- Some suppliers, after receiving full payment, installed the inferior systems. To resolve the problems, now only 50% of the total loan amount is paid initially. The balance is paid on completion of the work.
- Under the personal loan category, a large number of loans were procured by large commercial farmers, and the rural poor households did not benefit as much from the scheme as was intended. The scheme is on hold temporarily, and is under review.

7. Training and Consumer Education Needs

Lack of repair and maintenance support, inappropriate choice of devices and lack of user awareness and education result in the failure of solar systems and devices, loss of revenue and the loss of consumer faith in the solar systems. This in turn leads to social resistance to their acceptance. In order to mitigate this disabling environment, Government of Botswana had commissioned a study to recommend required training and education programs [5]. Education and training programs recommended by the consultants [5] embracing all the stake holders namely users, suppliers, installers, maintenance personnel, decision makers involved in procurement, and the public in general can be grouped into the following

broad categories.

- technical training programs for maintenance, installation and supervisory personnel;
- training program for procurement officers;
- user awareness and education programs;
- general education programs for schools and institutions of higher learning.

These recommendations are summarized in Fig. 5 [7]. Curriculum for the recommended programs can be found in Jain et al. [6] which can be used as guide by countries to formulate their own curriculum to dove-tail in their existing training programs for plumbing and electrical artisans.

Although, the study was undertaken in Botswana, the recommendations are applicable to most African countries with similar socio-economic conditions. Such training needs in most of these countries continue to persist because of the resource limitations and the lack of on-going RE programs in the country.

8. Conclusions

The two financing schemes from Botswana and Namibia for solar systems are able to remove the burden of large initial investment in RE systems by the rural poor consumers with limited resources. Consumers only need to pay affordable monthly installment either as a fee-for-service charge under the Botswana financing scheme, or as loan repayment at subsidized rate of interest in Namibia. Initial investments by service providers and the entrepreneurs are facilitated through franchising of businesses by the BPC Lesedi Company in Botswana and through the loan guarantee by the Government in Namibia. Long term success of both the schemes shall be determined from two factors:

- Efficiency of collection of monthly instalment with minimum incidence of default, and on keeping the repossession of the systems from defaulting users as low as possible.
- The volume of uptake of the products and services by the communities for whom they are intended. If a break even volume of uptake is not achieved and maintained, both the schemes shall run the risk of unsustainability because of large overheads for the franchised businesses and the rural SET enterprises.

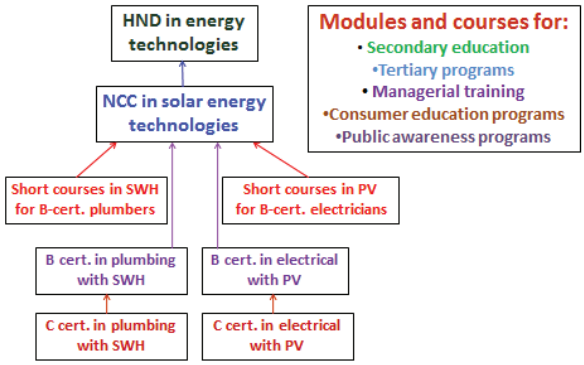

Fig. 5 Flow chart of the recommended training programs in RE technologies.

The two financing schemes are also able to resolve the problems relating to repair and maintenance of the systems either through the franchised business in Botswana or through the rural entrepreneurs in Namibia.

However, the importance of training, education and awareness programs at all levels involving the users, suppliers, installers, maintenance staff and decision makers in the procurement chain, cannot be over emphasized. One missing link of training could seriously affect the success of sustainable implementation of solar energy technologies on one hand, and could compromise building of the consumer faith in the products on the other.

Broad guidelines for the necessary training initiatives have been presented here which can be adapted to suit the local needs. The responsibility of training rests with the appropriate government agencies, and requires financial commitment and monitoring of the quality and standards to attract potential trainees. Thus, development of solar industry will open new venues of job creation, and will diversify economic opportunities. Poverty reduction and improved health, education and living standards will be eventual benefits reaped.

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