Experiences and Lessons in the Implementation of Solar Home Systems from Zimbabwe

Presented At The Domestic Use Of Energy Conference, Cape Technicon, Cape Town, 1-3 April 2002

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Abstract

Zimbabwe went through a period characterised by vigorous rural development efforts after independence in 1980. South Africa is currently going through a similar phase. The common aim is to redress the effects of past neglect of rural development.

One of the larger projects implemented in the mid 1990’s in Zimbabwe is the Global Environmental Facility - United Nations Development Programme (GEF-UNDP) funded solar photovoltaic project. It has been estimated that a total of about 85 000 solar home systems are installed in Zimbabwe today. Many of the companies that survived on installation of solar home systems during the GEF project collapsed when that project ended in 1998. The result was that many solar home systems were left without maintenance backup and their status is largely unknown. This paper highlights some experiences from Zimbabwe’s solar photovoltaic initiatives.

1. Introduction

About 5 percent of rural households are connected to the electricity grid, with small solar home systems (SHS) and the use of car batteries being common. Kerosene is widely used for rural household illumination using simple wick lamps, and for cooking in some urban households. Wood is the universal cooking fuel for rural households. Crop residues are used seasonally. Urban households electrification is relatively high, over 90% in Bulawayo, the second largest city and over 80% in Harare, the capital city.

It has been estimated that Zimbabwe has a total of some 85 000 solar home systems, which would make it one of the countries with the largest number of solar home systems in the region. It is however clear that the majority of these systems were installed outside any government or donor sponsored projects. When the numbers of systems installed by projects are added up, the total is unlikely to reach 20 000. The paper is largely based on a survey that was conducted in Sanyati, Kadoma district, in Mashonaland West province of Zimbabwe late in 2001.

Many people are known to import low cost modules from Botswana and South Africa, mostly these are amorphous silicon types. Amorphous modules are also sold in Zimbabwe. People buying modules in this way would buy batteries and set up their own systems or use the services of technicians who may or may not be knowledgeable about SHSs.

There are also Zimbabwean companies that sell do-it-yourself solar kits. The client buys a set of system components and will set up the system independently.

2. Major Solar Home System Initiatives In Zimbabwe
The most well known PV project undertaken in Zimbabwe to date is the GEF/UNDP/Government of Zimbabwe PV Solar Project, implemented between 1993 and 1998. This was not the beginning of the installation of PV systems in Zimbabwe. The market was active since the early 1970's, and the majority of PV systems in place were not in fact installed under this project.

The number of solar systems in Zimbabwe has been estimated at about 85 000 [1]. It is known that the number of systems installed by the GEF Solar project is around 12 000 [2]. The number may vary depending on how the systems are counted. The GEF project was using the 45 watt equivalent system as the unit. This does not translate to number of physical installations since, for example, a single 90 watt installation would be counted as two equivalent systems. The World Bank Energy Sector Management Assistance Programme (ESMAP) [1] has estimated that there were about 15 000 systems installed in Zimbabwe prior to the start of the GEF project. In addition the Japan International Cooperation Agency (JICA) funded a project that installed a few hundred systems between 1997 and 1998.

From the above figures it can be assumed that these special projects installed less than 20 000 systems. This means at least 65 000 systems were installed outside projects. This balance of solar home systems will be assumed to be in the category of do-it-yourself systems, which many people procure as kits, and set up themselves.

The GEF Solar Project in Zimbabwe was intended to address the issue of global warming and greenhouse gas emission by providing a sustainable model of solar electricity dissemination in Zimbabwe's rural areas in order to supplement grid electricity extension where it was not cost effective [2]. Zimbabwe was awarded a US$7 million solar photovoltaic project, which was intended to provide more than 9 000 PV home systems. Intended beneficiaries were rural households, small rural businesses, community establishments (churches, schools, clinics, cooperatives, district councils etc) and commercial farms (workers housing units).

The main delivery modes were national electric utility, the Zimbabwe Electricity Supply Authority (ZESA), private enterprises and non-governmental organisations (NGOs). Over the five-year period about 12 000 x 45-watt equivalent systems were delivered under subsidised conditions. The subsidies were in the form of government duty waiver on imported components, and a low interest rate of 15% per annum (compared to the prime rate of around 23% in 1997) for clients purchasing systems under the project. Over 50 companies and a few NGOs were active in the solar energy field by the time the project ended.

In 1997 the Department of Energy, and the Japan International Cooperation Agency (JICA) decided, as part of the elaboration of an electrification master plan in Zimbabwe, to run a pilot Energy Service Company (ESCO) solar home system project in Zimbabwe. Two clusters of 50 households were selected in Kadoma district in Mashonaland West province after extensive consultation with stakeholders [3]. Local companies were hired to install the systems. A local NGO, the Biomass Users Network (BUN) was contracted to act as the energy service company (ESCO) and maintain the systems for a fee to be paid by each client to cover the cost of maintenance. About 30% of the fee was a contribution to a fund that would enable replacement of key system components when they failed, particularly the batteries, and, less frequently, charge controllers. Most installations were completed in 1998. Four maintenance technicians were trained at Kwekwe Technical College, about 150km from the project site. Selection of these trainees was competitive and was undertaken together with the local rural district council.

The best two trainees were subsequently contracted by BUN, with one of the two being a young lady school leaver. Each technician was provided with a bicycle and a toolbox, and was required to visit every installation monthly to complete data sheets and attend to any problems. The technician could also be called in between the regular visits in case of system problems. Random visits by a senior BUN officer were undertaken to selected households to check on the technician’s activities. This will continue till the middle of 2002.
The project has been running for four years, with most clients, who are peasant farmers, paying their maintenance fees annually after harvesting and selling their produce, which is cotton in most cases. Monthly payments are not practicable with such clients given their income patterns. The majority of clients in this project are households, though there are several business premises where systems are used for extending opening hours of shops or bottle stores selling beer and playing music for clients.

A major risk factor with annual payments is the variation in agricultural yields, which depends on the weather. Farmers can fall into arrears due to poor rainfall and if this happens successively then catching up with payments becomes difficult. The major advantage of the ESCO approach is that clients are assured of a high level of system maintenance due to the close proximity of the technician, and the dependence of the ESCO on client payments, which will not be forthcoming if systems are not working.

Operational problems revolve around the need to ensure that clients adhere to the stipulated operation procedures and avoid tampering with systems. Precautions taken include placing the battery and charge controller in a box that is locked, the keys being kept by a technician who visits clients regularly or when a fault is reported between such visits. All the padlocks in each area are keyed alike, which means the technician only need to have one key when visiting clients. Despite this there have been cases of clients tampering with the battery boxes to gain access to the battery to use it for other purposes or to disconnect it in order to use the system to charge other batteries for example.


A survey of 40 households with solar systems was carried out in 2001 in Sanyati, Kadoma district, in Mashonaland West province of Zimbabwe, using a small budget provided by SIDA/SAREC (Sweden) through the African Energy Policy Research Network (AFREPREN). There is a small Energy Service Company (ESCO) project maintaining a cluster of 50 SHS in the same area. The ESCO systems were excluded from the survey because their status is well known due to the presence of a resident technician who visits the systems every month. The survey covered GEF solar project systems, battery only systems and systems acquired privately.

The total number of solar home systems in the area is of the order of several hundred. The survey was intended to explore the status of solar home systems installed over the last few years and to identify major problem areas. The findings with respect to quality and long term operational problems are comparable to other developing countries [4],[5].

4. Findings and Conclusions

4.1 Design of systems

Most systems did not have charge controllers. This situation can be expected to lead to battery deep cycling and uncontrolled charging. All batteries found were of the automotive type (except one) and are therefore suitable only for shallow discharge cycling. Without protection from deep discharge, battery life would be short. Indeed it was found that the average life of the non-GEF group batteries was about 1.6 years, while the GEF group average was better at about 2.4 years [6].

The problem of overcharging was felt to be unlikely to occur since the matching of module to battery in virtually all cases was poor, with seriously undersized modules. The average load size was similar in both the GEF and private solar home systems, being approximately 20Ah and 18Ah per day respectively. According to system sizing calculation and assumptions made by the author, the module size required for this is about 100 Wp (peak watt), with a battery size of about 80Ah. The installed solar modules range from 25 to about 60 Wp, with the majority being towards the lower end of this range.

The charge controller is there primarily to protect the battery from overcharge and deep discharge. In this survey the majority of households did not have charge controllers, this group constituting 27 out of
40 households, or 68%. While the risk of overcharge is relatively small with small modules, the major cause of concern would seem to be the deep discharge of the batteries.

The absence of a controller raises the risk of battery damage. The privately installed systems are clearly at higher risk by having far fewer controllers. This is compounded by the higher prevalence of the lower powered and less robust but cheaper amorphous modules among the private systems (over 40%). There are also fewer fixed modules among the private systems while all the GEF project systems have pole or roof-mounted modules. The mounts used do not allow changes in module orientation once fitted.

While some households had roof-mounted modules, other households practiced basking their loose modules in the sun during the day and taking them indoors at night. Basking was predominantly practiced with low cost systems not procured with mounting hardware. In these cases it is unlikely that both orientation and tilt could be regularly optimised, and at ground level the risk of shading and dust would be obstacles to efficient energy capture by the modules. The risk of breakage is high due to the accessible position of the modules and the daily indoor/outdoor movement.

4.2 Income generation opportunities

It is useful to note that some 23% of households in the survey were found to be utilising their solar home systems to facilitate income-generating activities. The income generating activities included after hours (evening) baking, grading of vegetables for sale, making peanut butter, sewing, knitting and holding private lessons for groups of school pupils. This may contribute to the positive attitude towards solar home systems, which seems to go against the widespread disappointment with maintenance arrangements. The downside of income generation is the fact that some owners of battery-only installations reported that they were charging their batteries on local solar systems. In these cases, even though the owners of the solar systems were getting income in the form of charging fees, they were exposing their systems to the danger of undercharging since such systems were not designed to cope with adequately charging their own batteries plus other batteries of unknown capacity, and at unknown intervals.

4.3 Reliability in operation

In its annual report for 1997, the GEF Project Management Unit reported that 71% of systems had never failed at that stage. The ages of the systems that had not yet failed was not given. In the same report, the component contributing most to systems failures were batteries, accounting for 44% of all faults, with controllers and lights coming far behind at 25% and 20% respectively. In terms of reaction to reported faults, the GEF project report showed that 50% of faults were attended to within 3 months. Only 20% were repaired within one month of a report. A further 20% were repaired in 3-6 months, while the last 10% took over 6 months.

What is clearly worrying here is that even if a charge controller failed, in 80% of cases response came after more than one month. Such periods of waiting with no charge going to the battery would also result in dead batteries. The situation was therefore not satisfactory even in 1997.

The private systems in the 2001 survey seemed to fare better than the GEF systems in terms of fewer faults and repair success. One explanation for this could be that private systems buyers would, from the outset know that they are responsible for any maintenance and may have taken the trouble to find out in detail what they should do for routine maintenance. On the other hand, owners of project systems may have taken their responsibilities more lightly, assuming that they would have any necessary backup provided by the responsible project.

4.4 Maintenance

There were cases of owners adding battery acid to top up their batteries. This is wrong, as only water is lost when batteries bubble during charging, and only pure water should be added to replace the
Most successful repairs involved the users themselves paying the necessary monies to replace faulty components, which were almost always the batteries. Usually users of solar home systems are expected to be able to undertake certain maintenance tasks such as cleaning and greasing battery terminals, topping up battery water, and keeping the solar module clean and free of shade.

The numerical dominance of solar home systems installed by individual households outside any project is likely to continue in view of the high interest in the energy services provided by PV systems. However the high cost of solar home systems will also compel private buyers of these systems to continue to buy low cost components without necessarily ensuring a reasonable match between the components. There are also battery-only systems where batteries are often used to power radios and TVs. The general causes of premature battery failure are similar in most private solar home systems and battery only systems. This is repeated deep discharge of batteries because there are no charge controllers or other ways to allow the user to know when the battery is in distress. The other cause is that private buyers do not have sufficient information to select optimal components and to understand why their systems are not working well.

5. Options recommended to address the problems cited above

There is need for the provision of information that assists the user in matching components better. It is not useful to give highly technical data since the average user will not be able to confidently handle the calculations, or even understand the specifications. This recommendation means that the information needs to be packaged appropriately for the intended user of that information. This is particularly relevant in view of the fact that most users procure their systems independently.

The needs of existing systems have to be addressed by not only educating the users on why their systems are not performing well and batteries not lasting, but also to have small projects that address the upgrade needs of the existing systems. One clear area of need is for some indication of when the battery is being discharged too deeply. A normal imported electronic charge controller may cost the equivalent of US$50, which is one reason many solar home system buyers leave it out altogether. A way to achieve control at reasonable cost is to fit a simple indicator that shows a green light when system voltage is healthy, and red when the system voltage is low and battery usage needs to be discontinued. This can be a simple, low cost approach but it will require discipline on the part of the user to discontinue battery use when the indicator becomes red. This type of indicator can also be used in battery only situations.

The implementation of the above recommendations as projects can be difficult because many funders may not find this attractive, preferring projects where imported equipment can be sold. One way to go around that may be to require, as a matter of policy, that all new solar projects must allocate, say 10% of their budget to addressing existing problems. Another way is to mobilise and support the solar industry associations to take up the task of improving the condition of existing systems.

A different and more drastic step would be a moratorium on new solar home system initiatives for some time while a comprehensive programme to identify and rectify all problems of existing systems is implemented. The cost of such a programme can be partly met from charges to solar home system owners, but additional funding would be required, for example for the information dissemination component. In addition, system owners who paid for poorly-performing systems under past projects may justifiably object to what they see as yet another project which takes away more money from them without guarantees of satisfaction in the end.

Initiatives to deal with this situation must therefore include the following components:

- Ensuring that all future projects specifically include a long-term maintenance provision. This can be made a specific condition for the approval of the project. A precedent that can be cited
in this case is the requirement for environmental impact assessments (EIAs) for most major projects before government approval in many countries.

- Providing appropriately packaged information to rural consumers to empower them to intelligently select good solar components and have basic rules of thumb to make reasonable matching. This is necessary because there will always be informal selling of solar home systems components and the consumers are at the mercy of sellers who can be unscrupulous.

The inclusion of plausible long-term maintenance arrangements should be relatively easy to implement as it is aimed at organized projects and there is an identifiable forum for the necessary discussions. What is more difficult is how to deal with non-project solar home system problems because there are no ready-defined fora for both the sellers and the users. The solar industry associations can be made to bind themselves with self-regulation. Such an arrangement could regulate company installations and sales of kits but leave out systems built piecemeal by the owners.

The issue of maintenance of existing systems is complicated by their scatter, which makes it unviable for any small local company to try to provide regular maintenance services. A possible approach is to provide training opportunities for existing rural technicians such as those already dealing with radio and TV repairs, and auto electricians. If these technicians also become involved in solar home system repair, they may be better able to cope as they will not be reliant solely on solar home system repairs for a living. The downside of this proposal is the possibility that the amount of attention accorded to SHS may be less than that accorded to other repair work. One reason is that it would still be easier to attend to a car, radio or TV that the owner brings to the repair shop, whereas the solar home system cannot normally be brought for repair. The technician must travel to the site and will need to charge for this.

6. References


7. Bibliography

1. EDRC. 2001. SEED Project Video Interviews of Maluti and Mt Fletcher Areas, Eastern Cape Province. South Africa. EDRC. Cape Town.


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The paper is presented by Maxwell Mapako.

**Acknowledgement:**
This mini survey on which this paper is based was kindly sponsored by SIDA/SAREC (Sweden) through the African Energy Policy Research Network (AFREPREN). The principal author is a researcher in the AFREPREN network.