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TOWARDS A STREAMLINED CDM PROCESS FOR SOLAR HOME SYSTEMS

Case Studies in Selected Countries:

Swaziland

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SUMMARY

The Case Study of PV SHS under the CDM potential of a project in Swaziland shows an abatement potential of 2.1 tonnes CO_2 per system over its lifetime of 20 years.

G. SWAZILAND

G.1 Introduction

About 1,200[1] PV Solar Home Systems have been installed in Swaziland, a country in Southern Africa with just over 1 million inhabitants[2]. Only 3% of all rural households are connected to the electricity grid, while about 1% obtains electricity by means of PV. Most of the PV systems installed in the country can be found in areas that are supplied by the national grid, especially the areas close to major towns. Likely explanations of this situation are the generally higher incomes, higher exposure to electricity, combined with a high cost of a grid connection and the close vicinity of most PV retailers. Between 1997 and 2000, some 600 systems were sold by Solar International Swaziland, partly on a credit basis as organised by ECN together with Triodos Bank. Of these systems, there is broad knowledge on usage of the system, technical performance and other energy use.

Currently, as part of a long-term research programme at ECN (ENGINE), about 100 households have been revisited recently during a survey on technical performance of system and user satisfaction. A number of outcomes of this survey may be used in the case study; it was however never set up as a CO_2 abatement project, rather as a development / standard of living improvement activity. Therefore, no CO_2 abatement estimates or baselines have been calculated for the Swaziland case. The case study will focus mainly on empirical data that has been gathered during the last four years during research by IVAM and ECN.

G.2 Project Characteristics

The aim of the project was to increase the rate of deployment of PV Solar Home Systems for rural electrification by means of a credit scheme. People had to pay 25% of the system cost as down payment and pay the remaining of the system during 3 years at an average interest rate of 22%.

The systems applied in the credit scheme in Swaziland consisted of a 45 W_p polycrystalline module in an anti-theft frame, a 105 Ah deep cycle battery, a regulator, four high-efficiency lights, wires. The system was installed by the supplier. The system price averaged US$ 15 per W_p, including installation and retail margin. No financial provision has been made for the replacement of the battery. Other appliances powered by the SHS include television, radio and cassette players. The yield in average Swaziland conditions was estimated around 200 Wh per day. This is sufficient for an 11W light to operate a total of 18 hours.

G.3 Description and determination of GHG sources and system boundaries

Qualitative description of the project life cycle emissions

The Green House Gas sources of the project are considered to consist of rural appliances for lighting, to be displaced by a PV Solar Home System. The system boundaries for this activity will be the project of implementing 400 PV SHS in rural Swaziland.

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[1] Source: Review of the PV market in Swaziland, Evaluation of the Government PV Demonstration Project" (1999)

[2] July 2000 estimate, source: CIA World Factbook

Since the project introduces the PV SHS components, their life cycle emissions will be included in the calculations. The CO_2 generation related to the travel by experts needed to organise the project and the emissions related to the installation will be included in the calculations as well.

Quantification of the project emissions
The baseline emissions will be estimated by using survey data of rural household's use of fossil fuels for lighting (candles and kerosene) and car battery charging. The life cycle emissions of the system components will be estimated using the preliminary report "Environmental Life Cycle Assessment of Solar Home Systems" (2000) by Erik Alsema (University of Utrecht). For the system components, only the module and the number of batteries during the lifetime of the system will be considered.

Local transport emissions for installation were considered. Only the modules were imported from Europe, the remains of the system (including the battery) were produced locally.

The lifetime of the system is 20 years, including replacements of 1 regulator and 7 batteries.

G.4 Current rural energy situation

Energy use and expenditures of the households
Table 1 below depicts the amounts of energy that was estimated on the basis of a rural survey [Lasschuit 1994]. Since Kerosene is relatively difficult to obtain for a large part of the rural households, the use of candles is still widespread (> 90 % of the households). The survey results show only average energy use. Since households that have obtained a PV SHS are wealthier than average households, their energy use is also higher. Anecdotal data suggest a factor of two higher energy use for lighting than average households. The data in the table below have been corrected with this factor. The resulting energy use is also in line with rural average energy use in neighbouring South Africa.

Table 1: Baseline energy use

Utility/household	No. of hours/day	Energy source, e.g.:	Annual consumption	annual energy costs (US$/yr)
Lights	3.13	Kerosene	52.8 litres	
		Candles	409 pieces	36
Battery Charging		Car Battery	30 Charges	30

The distance of the households to the grid has a high variation, but most PV systems can be found relatively close to the grid. The chance of getting a grid connection however, is still very low due to the high investment cost necessary for a grid connection. This is mainly caused by the low population density, on average 62 persons per km^2. Most people in Swaziland would like to have electric light because of the fumes and fire hazards related to fossil fuel-types of lighting.

G.5 Key factors, influencing the project impact and/or the baseline

G.6 Project specific factors

Adequacy of system design to users' preferences e.g. number of lights as compared to other
The users are mostly satisfied with the performance of the PV system. However, there is strong evidence that the PV system does not rule out the lighting by means of fossil fuels. Preliminary results of a recent survey carried out in Swaziland, are shown in table 2.

Table 2: Use of lights next to PV SHS lights (Source: survey P. Lasschuit, 2000)

Question: Do you use other lights, in addition to your PV SHS lights?		
Answer	**Share of response (N=96)**	**Cumulative Share**
Yes, always	43 %	43 %
Sometimes	15 %	58 %
No	43 %	100 %

The above table shows clearly that there is remaining use of fossil fuels for lighting purposes. The savings for battery charging seem to be more substantial. From a survey in Namibia[3] for example, it turned out that after PV electrification, 90% of savings on battery charging is reported.

Other results of an earlier survey in Swaziland are depicted in Table 3. From this table it can be seen that not all users are supplied by sufficient electricity. This does however not necessarily relate to lighting needs.

Table 3: Restrictions of PV SHS capacity(Source: survey P. Lasschuit, 2000)

Question: Did you ever experience a flat battery?		
Answer	**Share of response (N=113)**	**Cumulative Share**
More frequently experienced flat battery	15 %	15 %
Flat battery only occurs once or twice a year	36 %	51 %
Never experienced a flat battery	37 %	100 %

The above table shows that the use of fossil fuel lights can only partly be explained by the restrictions of the system. Other possible explanations are the high mobility of light from kerosene lamps and candles. These lighting options give households more flexibility in the place of use and therefore remain in use.

Quality of the system

The system components were approved by ECN. There are reportedly very few problems with the systems. The systems were installed by the technician of Solar International Swaziland. After evaluation it turned out that the quality of the systems was very high with regard to installation. Maintenance instructions are included with the system. The installer instructs the user how to maintain the system as well. Replacements of components were all for the users account. If batteries broke down early, this sometimes led to cease of payments of the monthly instalments to SIS.

Type of financing and delivery mechanisms used

The systems were sold on a credit basis. The down payment was 23% of the value of the system, with instalments each month for a maximum period of 3 years. The price includes retail margin and installation, travel, 2 replacement bulbs. A few systems were sold for cash.

Theft

Theft of PV systems is an issue in Swaziland (1-3% of the systems), but it can be made assumable that the new owner will try to maximise the utility of PV SHS as well.

Satisfaction of the end-users about the system and income

The willingness to pay is found to be high among the customers, until the system breaks down. It turns out that a visit of the technician and repair of the SHS is necessary to ensure continued payments.

[3] Source: PV SHS in rural Namibia'', J.Cloin and P.E. Lasschuit [2000]

Type and level/percentage of SHS subsidy
No subsidy on products, the dissemination effort was carried out in an open market. The only indirect subsidy can be traced back on project personnel, for developing the market.

Conclusion on the performance of the PV SHS
All in all, the PV SHS disseminated in Swaziland have been performing relatively well. Given the problems found in the field with batteries and controllers during the first three years, combined with the households that report a frequent empty battery, we assume a **total system availability factor of 80%.** This implies that during 20% of the time the PV SHS does not perform according to its potential and thus for lighting needs, households will fall back on use of fossil fuels.

G.7 External Factors

There are no kerosene subsidies in Swaziland. Its availability in the rural areas is unreliable; hence a large share of households who have candles as main lighting source. There are no subsidies on candles either. There is also no import duty on PV systems in Swaziland. The GDP real growth rate equals 3.1 %, but it is unclear what influence this will have on energy use. In most cases, the chance of rural electrification is small because of high costs[4].

G.8 Identification of baselines and selection of most likely baselines

For the case of Swaziland, a number of probable baselines have been developed. Given the moderate economic growth (3%), there will be difference in future energy consumption. Therefore, a moderate growth in energy consumption will be assumed. These different baselines are assumed to coexist while each baseline has its own probability to occur. Table 4 shows the 5 baselines to be expected, with a description of the energy use.

Table 4: Baseline formulation

Scenario	Description	Share of Systems
Baseline 1	no growth	10 %
Baseline 2	2 % p.a. energy use growth	50 %
Baseline 3	4% p.a. energy use growth	30 %
Baseline 4	Grid arrives after 5 years and PV SHS used as backup system (i.e. 5% of initial savings)	5 %
Baseline 5	Grid arrives after 5 years and PV SHS replaced after 1 year (i.e. no savings during one year)	5 %
	Total	100 %

Baseline 1 describes households that will use the same amount of energy for the next 20 years. Under baseline 2 and 3, the energy use will grow with 2 and 4 percent respectively. Baseline 4 describes a household that keeps its PV SHS after grid electrification for back-up purposes. This decreases its baseline emissions with a factor 20, starting in year 6. The last baseline describes the removal and the re-installation of a PV SHS from one household that is being grid-electrified, to another household that was still using fossil fuel lighting.

The selection was made by means of an estimation of the share of households that would fall into the baseline scenario. The estimated share of households is given in the most right column of Table 3. This baseline can be improved by actually surveying increase in energy use of the households. By doing this, the share of households following the scenarios can be re-estimated using empirical data.

[4] Source: Rural Electrification in Swaziland, July 1997; Jansen et al.

G.9 Estimation of energy services provided

The services provided by the system (Table 5) exceed the average use of fossil fuels for lighting purposes. Above that, the system is able to power a radio and TV for 12 and 2.5 hours respectively. It is assumed[5] that this service is equivalent to an average of 2.5 Car battery charges per month.

Yield		Potential Use	
Variable	Value	Appliance	[Hours]
Module	45 [W_p]	Lights	18
$U_{bat, charge}$	13.5 [V]	TV	7.2
# Sun-hours	5.5 [A]	Radio	36
SDABC[6]	5.5*(45/13.5) = 18.33 [Ah]	Or: 6 hours of light, 12 hours of radio and 2.5 hours of TV each day.	

Table 5: Estimated service by a PV SHS

G.10 Emission of the project

The total emissions (Table 6) of the project include the Life Cycle Emissions[7] of the system components, neglecting the contribution of the Balance of Systems (i.e. the regulator, wiring and lights). For the total emissions from a system, a standard average installation distance of 50 km per system is included. The total emission of the project is achieved by adding the necessary travel to Swaziland by experts for project management, resulting in roughly 310 tonne CO_2.

Table 6: Calculation of project emissions

Emission Source	Emission [kg CO_2]	
	Per System	
Module	85.5	
Battery	94.5	
BOS	-	
Installation emissions	12.5	
Total Life Cycle Emissions[8] per system		759.5
	Overhead	
Project Travel emissions (3* EU-SD return)	6,051	
Total project emissions (400 systems)		**309,851**

Survey findings[9] in Swaziland include amongst others a relatively short lifetime of the battery; 73% had to replace the battery within 2 years and 42% even within one year. The influence on the battery lifetime by a regulator in the system became clear as 35% of the systems with a regulator needed battery replacement within one year compared to 53% of the systems without a regulator. Most people throw their used batteries away or just keep them somewhere at home. A proper recycling system has not taken off as yet in Swaziland, creating a relatively high burden of PV SHS on the ecosystem. Therefore, an average battery life of 3 years is chosen for this case.

[5] 2.5 hours times 2 A implies 5*30 = 150Ah/ month. Based on discharge depth of 70%, this equals 3 charges of a 70 Ah battery.

[6] Standard Daily Average Battery Charge; calculation on basis of an average number of maximal-sun-hours multiplied by the maximum-charge-current. This figure has been adjusted for system losses.

[7] LCA emissions according to Alsema (2000)

[8] Based on battery lifetime 3 year.

[9] Source: 1998 survey, N=120

G.11 Emissions of the baseline

For the baseline calculations, the average amount of kerosene and candles, of six representative areas surveyed, has been used. This results in total baseline emissions of 217 kg CO_2 per household per year. From Table 7 it can be seen how this figure was calculated.

Source	Monthly use	Kg CO_2/month	
Kerosene for lighting	4.4 litres		12.2
Candles for lighting	34.1 candles		3.7
Car battery charging	2.5 Charges		2.3
Total baseline emissions[10] per month			**18.2**
Total emission of the baseline[11]		2,115,282	

In chapter 5 it was shown how that several baselines were chosen for different shares of the total number of households. This implies that over the coming 20 years, the households are expected to emit over 2,115 kilotons of CO_2.

G.12 Determination of crediting time

Since the PV SHS are expected to perform until the end of the PV module guarantee, the crediting time is set at 20 years.

G.13 Estimation of the emission reduction

The emission reduction is calculated as the subtraction of the baseline emissions minus the project emissions. Under baseline 1, the amount of fossil fuels for lighting to be displaced will stay equal. The next two baselines describe 2 and 4 percent annual growth in energy use

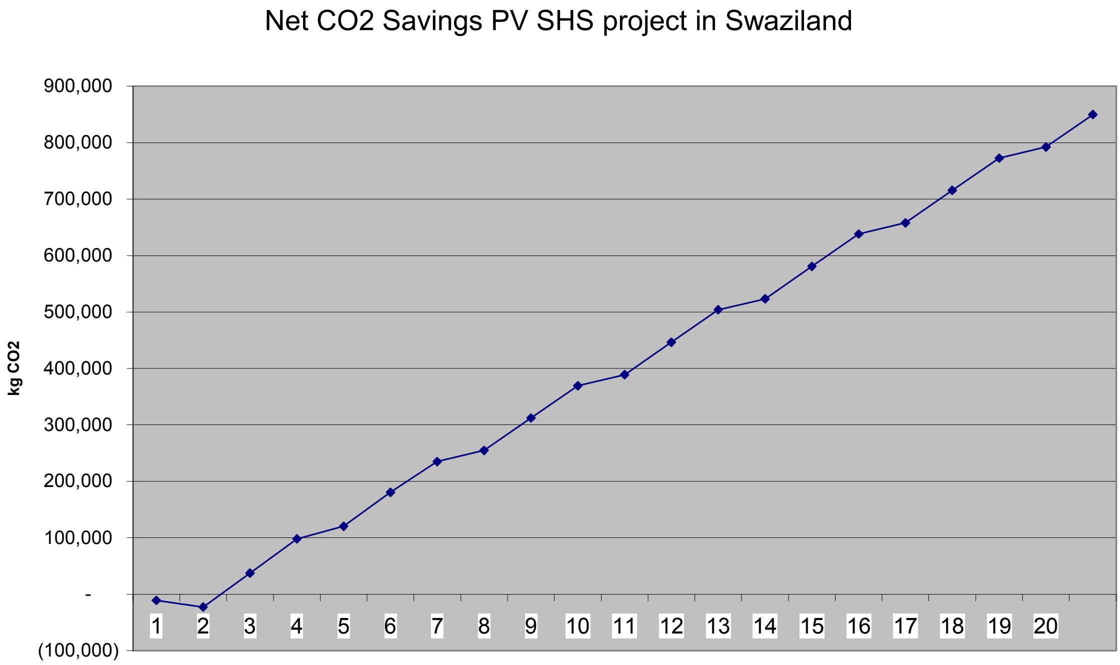

Figure 1: *emission reduction of 400 PV SHS in Swaziland as a function of time*

[10] The baseline emissions for candles and kerosene include 15% upstream emissions.

[11] Total emissions for 400 households following the described 5 baseline scenarios.

respectively. The amount of fossil fuel lighting displacement however, is assumed to be equal to baseline 1, i.e. the increase in energy use will still contribute to the use of kerosene lamps. Therefore, effectively, baselines 1, 2 and 3 will result in the same savings. Baseline 4 and 5 are calculated as described in chapter 5.

Figure 1 shows the development of the emission reduction over time. It can be seen that every three years new batteries are installed, decreasing the growth in emission reduction for that year. The total amount of saved CO_2 for the systems together is 850 tonnes, resulting in a saving potential of **106 kg / CO_2 per system per year.**

G.14 Evaluation of the additionality

Conclude on the additionality of the project
PV deployment (measured as annual sales) has increased by a factor 3 after the project took off, showing the additionality of the credit facility. The possible contribution of CDM to the decrease in price per system is considered minimal, therefore financial additionality will be difficult to prove for future projects.