TOWARDS A STREAMLINED CDM PROCESS FOR SOLAR HOME SYSTEMS

Case Studies in Selected Countries
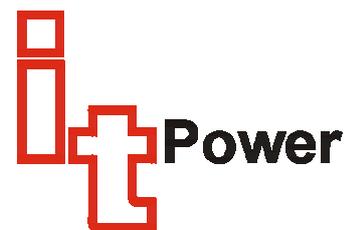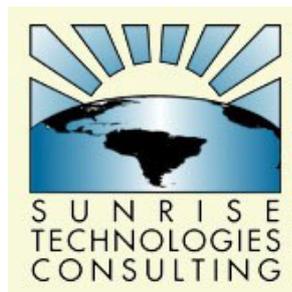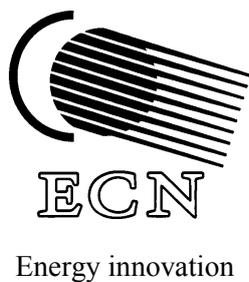
Energy innovation

SUNRISE TECHNOLOGIES CONSULTING

Power

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Argentina

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Acknowledgement

Abstract

This case study reviews a GEF/World Bank-supported rural electrification project involving SHS dissemination via exclusive concessions in Argentina. The case study focuses on aspects of the project that are most relevant to carbon abatement. Since the Argentina project will receive grant funding under the GEF's climate change portfolio, certain carbon abatement issues are addressed in GEF and World Bank project documents.

SUMMARY

The Renewable Energy in the Rural Market Project supports an innovative approach to rural electrification in Argentina using exclusive concessions to supply dispersed rural homes and public facilities with renewable energy systems on a fee-for-service basis. The project's SHS component seeks to install 65,500 individual systems over six years. Currently, off-grid rural Argentine households use kerosene and candles for lighting, dry cell batteries to power radios, and centrally charged car batteries to power black and white TVs. The systems will replace kerosene lighting with electric lights and will power small appliances such as radios, radio/cassette players, and TVs. The project's carbon abatement calculations are based on kerosene displacement by solar powered lights. Following a format outlined in a questionnaire provided by ECN, this document reviews general project characteristics and focuses on aspects of the project that are most relevant to carbon abatement.

A. ARGENTINA

A.1 Project characteristics

A.1.1 General project information

The World Bank/GEF-supported Renewable Energy in the Rural Market Project, or 'PERMER' (Proyecto de Energía Renovable en el Mercado Eléctrico Rural) will advance Argentina's efforts to have private companies supply electricity in dispersed rural markets through exclusive concessions at the provincial level. GEF documents prepared in 1997 (i.e., Project Information Document and Proposal for Review) and the World Bank's Project Appraisal Document (PAD) from 1999 provide general project information and many details. Several reports by the Argentine government and others provide additional information about the project and the development of dispersed rural electricity concessions in Argentina.

The PERMER project will support part of Argentina's PAEPRA program (Programa de Abastecimiento Eléctrico a la Población Rural de Argentina), which was established in 1995 with the intention of supplying electricity to 314,000 off-grid rural homes and 6,000 public facilities in 16 provinces. PERMER seeks to supply about 65,500 rural homes with SHSs (ranging in size from 50 to 400 W_p) in at least 8 Argentine provinces; it also aims to electrify 1,100 public facilities with photovoltaic systems and 3,500 'amalgamated' homes (in communities of 15 to 50 households each) via mini-grids using some combination of hydro, PV, wind, and/or diesel generating systems, with the specific technology to be selected at the concession holder's discretion. Eight out of 22 Argentine provinces are currently eligible to participate in the PERMER program. (Source: GEF project documents and World Bank PAD).

The PERMER project will provide subsidies to help bridge the gap between households' historic energy expenditures and the higher cost of the electricity service provided by the concession holders. To minimize subsidies, concessions will be awarded to qualified bidders who require the lowest amount of subsidy to provide electricity service at specified levels. The concession holders will be obligated to: provide electricity to all rural off-grid customers requesting service anywhere in the province; conduct all maintenance, repairs or replacement of components as needed to ensure continuity of the electricity service to each customer; and provide the provincial utility regulators with periodic reports on the status of the concession-- including performance indicators such as number of connections by type of consumer and technology, outage statistics, and financial results. Concession contracts with the provinces will last for 15 years, after which concession holders may re-bid through a competitive process. (Source: Eric Martinot, Ramesh Ramankutty, and Frank Rittner, Thematic Review of the GEF Solar PV Portfolio, June 2000 draft)

The Project Appraisal Document indicates that $5.8 million[1] of the $10 million GEF grant will directly support the installation by concession holders of about 55,300 SHSs by financing the incremental costs for 50W_p, 70W_p, and 100W_p systems. Concession holders will also install about 10,200 larger systems that will not receive direct GEF subsidies. The remainder of the GEF grant will support a range of activities intended to build a well-functioning renewables-based rural electrification program including: capacity building programs to remove barriers to renewable energy; detailed market studies to reduce concessionaire risks; SHS and public education programs; feasibility studies for centralized renewable systems; dissemination workshops; and standards and certification systems for equipment and installers.

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[1] All dollar figures referred to in this case study are in US$ terms.

GEF subsidy for SHS purchases (in US$) will decline over a five-year period as follows:

SHS size	Year 1	Year 2	Year 3	Year 4	Year 5
50Wp	125	125	120	105	70
70Wp	105	105	100	90	60
100Wp	85	85	80	70	45

Source: Project Appraisal Document (Report No. 17495).

The World Bank's Project Appraisal Document estimates that the project will displace between 0.8 and 1.1 million tons of CO_2. Project documents refer to avoiding both kerosene lighting and diesel-powered electricity generation; however, the project's GHG benefit calculations are based exclusively on kerosene displacement (as explained later).

A.1.2 Project Objectives

The World Bank's Project Appraisal Document says PERMER's objectives are to:
a) Provide rural areas with reliable electric supply in a sustainable manner, using renewable energy technologies where feasible;
b) Support the creation of sustainable business operations for rural energy in Argentina;
c) Support the expansion of private sector participation in the provision of electricity in rural areas and the corresponding strengthening of provincial government capacities to regulate that participation; and
d) Advance the reform of the energy sector in particular critical areas.

The 'global' GEF objectives are to:
a) Remove market barriers to the dissemination of renewable energy sources; and
b) Reduce greenhouse gas (GHG) emissions by replacing small diesel electricity generation and the use of candles, kerosene and gas cylinders (for lighting and other domestic uses) with renewable energy systems (RES). (Source: Project Appraisal Document, World Bank 1999.)

A.1.3 Description of the SHSs used in the project

The GEF and World Bank project documents reviewed for this case study supply limited technical information about the SHSs to be used in the project, but technical information may be specified elsewhere (e.g., in procurement guidelines or concession bidding documents). Other sources provide information on the SHSs used in the provinces of Jujuy and Salta, which are among the first to have implemented rural electricity concessions.

System sizes
GEF and World Bank documents say that systems will range from 50 to 400 W_p. Surveys indicate that 50 to 100 W_p systems will dominate (Project Appraisal Document).

Type of modules
The GEF and World Bank project documents reviewed for this case study do not specify module type, but procurement guidelines or concession bidding documents may.

Type of batteries
The GEF and World Bank project documents reviewed for this case study do not specify battery type, but procurement guidelines or concession bidding documents might.

Number and type of lights
In Jujuy Province, one report suggests that systems are coupled with lights as follows:
50 W_p – 2 of 11 watts
70 W_p – 2 of 11 watts
100 W_p – 2 of 15 watts
150 W_p – 1 of 15 watts and 2 of 11 watts
200 W_p – 1 of 15 watts and 2 of 11 watts
(Source:Alvaro Covarrubias and Kilian Reiche, 'A case study of exclusive concessions for rural off-grid service in Argentina,' in Energy Services for the World's Poor; Washington, DC, World Bank Energy Sector Management Assistance Programme, 2000.)

Other components
In addition to lights, systems will be designed to power radios, radio cassette recorders, and televisions.

System quality
GEF proposal documents indicate that the concession holder must create the necessary infrastructure to supply and operate the SHSs in a sustainable manner and ensure that all systems comply with technical specifications.

Number of systems installed
The Project Appraisal Document estimates that a total of 65,500 SHSs will be installed: 55,300 in the 50 to 100 W_p range and 10,200 in the 150 to 400 W_p range. To date, the rural electricity concession holder in Jujuy has installed at least several hundred SHSs. The concession holders for Salta, and perhaps some other provinces, have also installed systems. The World Bank/GEF PERMER money, however, has yet to be disbursed, so as yet no installations have been GEF-subsidised. The World Bank's task manager anticipates initial GEF and World Bank disbursements to Jujuy very soon[2].

SHS market experience in the region
GEF and World Bank project documents provide substantial background on the rural electrification situation in Argentina and the country's work to develop the dispersed rural electricity market program; however, they do not specifically address the country's experience with SHS. An Argentine government report says that by 1997 the country had about 1 MW of PV installed in applications ranging from cathodic protection to navigational signals. According to one estimate, about 2,000 SHSs are now installed in Argentina, apart from installations by the rural electricity concessions.[3] While the Argentine government had previously promoted PV use for rural schools, there seems to have been no comprehensive initiative to build lasting SHS markets prior to PERMER.

A.2   GHG Sources and System Boundaries

While GEF and World Bank documents do not explicitly specify geographic system boundaries, conversations with bank staff and a spreadsheet used to calculate the project's GHG benefits indicate a system boundary around individual rural homes. No emissions were assumed from the systems themselves, but some continued kerosene lighting was anticipated. Upstream emissions were not explicitly considered[4].

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[2] Source: email from P. Durand on October 3, 2000

[3] Personal communication with Enrique Grünhut, Technology Manager, Energy and Environment Centre, INTI (National Institute of Industrial Technology) ARGENTINA, October 19, 2000.

[4] Source: Spreadsheet provided by Ernesto Terrado

GEF and World Bank documents estimate GHG benefits over 15 years, corresponding with the period over which the concession holder agrees to supply SHSs for electric service.

A.3   Current Rural Energy Situation

Current energy consumption
The GEF Proposal for Review supplied the following:
Based on government of Argentina surveys of the dispersed areas in four provinces, the households without grid electricity belong to essentially four levels of energy expenditures:

Income Type	Income/month	Percent of Households	Energy Expenditures/month
I	Less than $150	19%	$10.06
II.	$150 to $250	40%	$14.94
III.	$250 to $400	27%	$24.95
IV.	Greater than $400	14%	$38.12

* Energy expenditures are for kerosene, candles, dry cells and battery charging. These values are levelized monthly expenses, including replacement costs.

Population density and distance from the grid
The Argentine government, together with provincial authorities, identified areas that could receive grid electricity service in the near term and ones that would be better served using off-grid electrification. All of the households eligible to participate in PERMER fall into the later category. Areas selected for the dispersed service have comparatively low population density as well as low power consumption.

The GEF Proposal for Review made the point that population density would affect the operating costs of the businesses providing SHS services: 'Through GIS data and information on O&M costs in the Jujuy and Salta concessions, SEP [Secretariat of Energy and Ports] has calculated that reducing the number of kilometres per consumer serviced per month will reduce O&M costs per unit from $4.96 to $3.71 per month or an NPV of about $56 per unit, as the number of customers increase from 100 to 350 for each maintenance team.'

Adequacy of current situation
GEF and World Bank documents anticipate substantial quality-of-life benefits associated with switching from kerosene lighting, dry cells, and battery charging to the clean electric power supplied by the PV systems.

A.4   Key Factors Influencing the Project's Impact and/or the Baseline

A.4.1 Project specific factors

Quality of the system
The GEF Proposal for Review says 'the concessionaire will create the necessary infrastructure to supply and operate the SHS in a sustainable manner. All SHS will be required to comply with technical specifications, ensuring quality products and services. ' The World Bank Project Appraisal Document says '[t]o ensure quality installations, equipment components, systems and installer qualifications will need to satisfy internationally accepted standards. GEF grants will partially finance certification costs.'

The World Bank Project Appraisal Document further states that the project will supply technical assistance to develop national standards and certification systems for PV systems, components and installation procedures. This is intended to create an ongoing system to ensure the efficient,

reliable and rational development of SHSs in Argentina. While the accreditation and certification requirements would be to global standards, they would be administered by the designated in-country administrative organization, which would participate on a global and regional basis with other foreign and regional member organizations. The project provides $300,000 for this task.

Adequacy of system designs
The extensive technical assistance provided by this project should ensure that systems are designed to adequately meet users needs and preferences. Furthermore, concession holders will have a strong incentive to ensure customer satisfaction in order to maintain high monthly payments rates.

Replacement parts and maintenance
For the 15 year concession period, the concession holder will be obligated to provide continued service, which will require that they conduct system maintenance and parts replacement as needed. Since the concession holders will receive monthly payments for SHS service from end-users and government-supported subsidy programs, they will have an incentive to properly maintain the systems. The concession structure should help to assure continued system functioning.

System financing and delivery
The concession holders will offer SHSs on a fee-for-service basis.

Type and level of SHS subsidy
Subsidies are a significant feature of the PERMER program. In addition to the GEF subsidy (for 50 to 100 W_p systems) the provincial governments will use Argentina's Electricity Investment Development Fund and a portion of the World Bank loan (which will be transferred to the provinces as a grant) to provide an up-front subsidy to all rural households obtaining systems of 400 W_p or less. In some cases, provincial governments will also provide a subsidy financed through the Tariff Compensation Fund to help very low-income rural consumers make their monthly payments.

A.4.2 External Factors

Kerosene subsidies
The GEF and World Bank project documents do not identify kerosene subsidies as a factor that could affect the SHS project and do not indicate whether kerosene is subsidised in Argentina.

Grid extension plans
It seems pretty certain that the project will not be affected by grid extension. 'In creating PAEPRA, the Argentine government used a geographic information system to determine which areas in each province are too sparsely populated and/or too far from existing power lines to connect to the grid cost-effectively during the short to medium-term. The government published maps delineating these regions and estimated a total unelectrified population of 2 to 3 million, thereby addressing the market barrier created by grid-extension uncertainty.' (Source: Regulating for Renewable Rural Electrification, by Nathanael Greene, Richard Duke, and Dale Bryk for Natural Resources Defense Council, Draft November 1999).

Legal aspects
The concession approach provides some assurance that legal and regulatory treatment should be relatively predictable over the 15 year concession period.

Socio-economic and demographic developments
The GEF and World Bank project documents do not identify any socio-economic or demographic developments that would affect the project. The World Bank Project Appraisal Document forecasts the prospective SHSs market at 50% of the off-grid population in the targeted provinces and says that some of the off-grid population would not be able to afford SHS service. Raising rural incomes would expand the SHS market by increasing the number of households which could afford SHS service as well as increasing average system size.

Other
According to the Project Appraisal Document, World Bank experience in India indicates that government incentives such as taxes, duties, and subsidies, must be consistent with project objectives in order to maximize long-term impact. It says that 'the current incentive framework in Argentina is largely satisfactory. The import duties do not discriminate against RES. The Congress approved a law that provides incentive to the use of solar and wind based RES by spreading the payment of the value added tax over 15 years.'

A.5   Baseline Identification and Selection

How many baseline options have been considered
The project documents refer to two possible baseline scenarios for supplying lighting and powering small appliances (i.e., radios and TVs) in dispersed rural homes: individual diesel generation and continued dependence on traditional energy forms (i.e., kerosene, dry cells, and battery charging).

Baseline selected
The project's carbon displacement calculations use a kerosene lighting baseline exclusively. As explained below, the kerosene consumption estimates use generic figures that are not specific to Argentina.

Do you believe this was an appropriate baseline, and how could it be improved?
The baseline selection seems reasonable to provide a rough estimate of the global environmental benefits from the project. A scenario assuming that some households would receive electric service via individual diesel generators might also be reasonable in this case. To be more accurate, the baseline estimates could potentially be improved by using kerosene consumption data specific to Argentina, rather than generic international figures, and could calculate and include avoided emissions from battery charging. Furthermore, the baseline calculation methodology assumes that kerosene displacement will increase in proportion to module size. Evidence from Kenya suggests that, while larger SHSs displace more kerosene than smaller ones, the increase is not proportional to module size.[5] Survey data from Honduras found no correlation between kerosene displacement and module size for systems predominately in the 40 to 70 W_p range.[6] While the assumption of proportional increases in kerosene displacement seems unrealistic, this assumption's impact on the project's overall carbon displacement estimates should be small since most systems are expected to use comparatively small modules.

A.6   Estimation of Energy Services Provided

Concession bidding and contract documents specify the level of service the concession holder must supply to different categories of off-grid household customers. The lowest level of service is about 4 kWh per month.

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[5] Robert van de Plas and Mark Hankins, Solar Electricity in Africa: a Reality, Energy Policy, Vol. 26, No. 4, pp. 295-305, 1998.

[6] Unpublished 1999 study by Brown University student Maria Reff.

In Jujuy, systems are offered in 5 sizes:
50 W_p supplying 3.75 kWh/month
70 W_p supplying 5.25 kWh/month
100 W_p supplying 7.5 kWh/month
150 W_p supplying 11.25 kWh/month
200 W_p supplying 15 kWh/month
(Source:Alvaro Covarrubias and Kilian Reiche, 'A case study of exclusive concessions for rural off-grid service in Argentina,' in Energy Services for the World's Poor; Washington, DC, World Bank, Energy Sector Management Assistance Programme, 2000.)

In Salta, systems are available in 3 sizes:
150 W_p providing about of 11 kWh / month
200 W_p providing about 15 kWh / month
300 W_p providing about 22 kWh / month

A.7   Project Emissions

GEF and World Bank project documents make no reference to upstream emissions and do not present a life-cycle emissions analysis. A spreadsheet used to calculate the carbon benefits expected from the project (provided by Ernesto Terrado of the World Bank) uses an assumption that the solar home systems would displace kerosene 350 days out of the year.

A.8   Baseline Emissions

How was the calculation structured?
The spreadsheet used to calculate carbon reductions uses two figures for average kerosene consumption for lighting in unelectrified rural households (one from a study by deLucia and Associates evaluating a proposed GEF SHS project in Indonesia and another from ESMAP); apparently neither was specific to Argentina. The figures were assumed to represent the amount of kerosene that could be displaced by a 50 Wp SHS. To calculate the amount of kerosene displaced by larger systems, the figures were scaled up proportionately (i.e., a household obtaining a 100 Wp SHS was assumed to burn twice as much kerosene for lighting as one with a 50 Wp system). An emission factor was used to convert from kerosene to CO_2.

What values have been used?
Average kerosene consumption per household for lighting: 0.5 to 0.7 litres per day.

Emission factor: 2.4 kg CO_2 per litre of kerosene burned. This assumes kerosene is 86% carbon with a density of 0.8 kg/litre and kerosene lamps have a 95% combustion efficiency. As mentioned above, systems were assumed to displace kerosene 350 days out of the year.

A.9   Determination of crediting time

The emissions displacement benefits are calculated over a 15 year period, which corresponds with the life of the concession contract and the assumed life of the SHS.

A.10   Estimation of the emission reduction

The World Bank project appraisal document estimates total abatement of between 0.8 and 1.1 million tons of CO_2.

The author's estimate, based on the emission factors and calculation methodology supplied by the World Bank (which used installation figures for an earlier, larger version of the Argentina project), yield's very similar figures.

A.11 Evaluation of additionality

Explain why the project would not be undertaken without being a CDM project given both the existing situation (costs, income distribution, technical status of equipment, regulation etc.) and the future situation (planned grid extension, income development etc.)

The government of Argentina prepared the rural concessions policy framework for dispersed electrification using renewable energy in its PAEPRA program prior to obtaining World Bank and GEF funding under PERMER. But, financial constraints reportedly limited the program's ability to move forward without the external funds provided by PERMER. The GEF aspect of the project supplies funds to make SHSs affordable to end-users who would not otherwise be able to obtain them, and supports other activities to build a well-functioning SHS dissemination program. As structured, the project would not have happened (at least not at the same scale or speed) without the funds directly mobilized in the interest of climate change mitigation.

Confirm that the project would not be undertaken with ODA sources as CDM projects should be additional to ODA

PERMER is a GEF-supported effort and would therefore probably not qualify for the CDM.

Conclude on the additionality of the project
While PERMER receives support from the GEF, this same type of activity would be 'additional' if it were sponsored privately or with public funds that were not ODA. If other Argentine provinces, not participating in PERMER, operate their concession programs without GEF or ODA support then their SHS activities should be eligible to participate in the CDM.

How do you see this for future projects?
Additionality requirements excluding projects that receive GEF and ODA support will almost certainly be an issue in the case of SHS activities. There are over 20 GEF projects supporting SHS activities in numerous countries, including 'global' projects such as the Solar Development Group and PVMTI that are designed to be implemented in multiple countries. Furthermore, several countries have provided bi-lateral development assistance to support projects involving SHS initiatives and other measures for rural energy supply using renewable sources of energy.

It would be unfair and counterproductive to restrict CDM eligibility to only those companies and countries that have never received GEF or ODA support to initiate or stimulate SHS activities. For example, it would be unfair to make Argentine provinces that are not participating in PERMER ineligible for the CDM simply because GEF funds have been used to support SHS activities in Argentina. The simplest approach to excluding SHS activities benefiting from GEF and ODA funds would be to require that no SHS installation be eligible for CERs if it has been directly financed with GEF or ODA funds.

Honduras

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Acknowledgement

Abstract

This case study reviews a solar-based rural electrification initiative in Honduras, focusing on aspects of the project that are most relevant to carbon abatement. Since the Honduras project was structured to participate in the U.S. Initiative on Joint Implementation (and subsequently the Activities Implemented Jointly pilot program of the UN Framework Convention on Climate Change), aspects of the project related to carbon abatement are detailed in existing documents. While most of the project's carbon-related aspects are well understood, there are still some areas of uncertainty. Since the project has not yet been formally monitored, there is some uncertainty regarding the amount of kerosene homeowners used for lighting both before and after their SHS installation. Based on different interpretations and possible methods for determining additionality under the CDM, there is also uncertainty regarding the project's eligibility to generate Certified Emission Reductions.

SUMMARY

The Honduras solar-based rural electrification project seeks to make solar technology available and affordable in the Honduran countryside. Initially structured in late 1994 as an NGO activity focused on solar technician training and consumer financing, the project was expanded in 1998 to include a solar home system (SHS) fee-for-service operation. Currently in rural Honduras, households use kerosene, candles, and in some cases biomass for lighting. They also commonly use dry cell batteries to power radio/cassette players and grid-charged car batteries to power black and white TVs. The Honduras project focuses on the segment of the rural population that principally uses kerosene for lighting. The systems replace kerosene lighting with electric lights and supply electricity for TVs, radio/cassette players, and other small appliances. Project participants have calculated carbon abatement based on kerosene displacement by solar powered lights. Following a format outlined in a questionnaire provided by ECN, this document reviews general project characteristics and focuses on aspects of the project that are most relevant to carbon abatement.

B.   HONDURAS

B.1   Project characteristics

B.1.1   General project information

The Honduras AIJ project's November 1994 application to participate in the United States Initiative on Joint Implementation (USIJI) provides general background. Project information has been updated annually in reports submitted by the US government to the UNFCCC Secretariat using the uniform AIJ project-reporting format.

As the USIJI application explains, the Honduras solar-based rural electrification project is designed to make photovoltaic technology available and affordable for rural Honduran households. Well over two million residents of rural Honduras (in approximately 390,000-plus households representing about 88% of the rural population) live without access to an electric grid.[7] Experience shows that SHSs can be a viable, cost-effective way to supply electricity in rural Honduras, but there are still several barriers to SHS dissemination, including lack of information about the technology, lack of SHS availability in some rural areas, and the high up-front system costs.

As initially conceived, the AIJ project was to use new funds to expand a pilot program being implemented by Enersol Associates and collaborating Honduran participants using a model developed by Enersol in the Dominican Republic. Enersol's model uses training and technical assistance to develop small businesses that sell, install and maintain solar electric systems in rural areas. To make the systems affordable, local NGOs operate credit programs for system financing. In the Dominican Republic, this model and subsequent commercial activities led to over 10,000 SHS installations, representing about 2 percent of off-grid Dominican households, by mid-2000. From 1992 until 1998, Enersol worked to replicate the model in Honduras, resulting in about 3,000 SHS installations by mid-2000.

After the AIJ project documents were submitted and the project was accepted into the USIJI program in 1995, Enersol, its local affiliate ADESOL, other Honduran NGOs, and a coffee cooperative, continued to engage in solar energy micro-enterprise development and consumer credit activities. Since the activities were funded as they had been previously, and did not receive money from new, carbon-motivated sources, (e.g., companies seeking carbon offsets or investors interested in carbon abatement), Enersol did not consider those activities to be part of the official AIJ project. In 1998, Enersol decided to shift its role in Honduras to one of helping to supply renewable energy systems for health and educational purposes (e.g., clinics, schools, and community water pumping). Enersol no longer provides SHS consumer credit through NGOs and is no longer involved with SHS energy enterprise development.

In 1998, Enersol's commercial affiliates Soluz Inc. and Soluz Honduras were added as participants in the AIJ project. These Soluz companies and their investors are motivated in part by an interest in carbon abatement. While there is still the potential for NGO involvement in SHS dissemination under the Honduras AIJ project, Soluz Inc. and Soluz Honduras are now implementing the project through their SHS fee-for-service program.

Lack of access to capital is a major impediment to widespread SHS dissemination in rural Honduras. Only an estimated three to five percent of un-electrified Honduran households can

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[7] Honduran Census data for 1988 show 391,959 rural households without electricity.

pay cash up-front to purchase a system. Consumer credit can increase the market considerably, but still only an estimated 20 percent of the un-electrified population could afford to buy systems with three-year loans at commercial interest rates. To reach more people, alternative financial arrangements are needed. The Soluz 'fee-for-service' program offers one such option. While this was anticipated in the original USIJI application, such arrangements had not yet been initiated in Honduras at the time; now they are underway.

B.1.2 Project Objectives

The USIJI application indicates that the overall project objectives are to make SHSs available and affordable in rural areas of Honduras through a combination of technician training, solar energy enterprise development, and consumer financing.

B.1.3 Description of the SHSs used in the project

Type of modules
The USIJI application and subsequent annual reports do not specify the size or type of PV modules to be used in the project.

In the Honduran market, solar home systems typically use 50 W_p and 75 W_p modules. Soluz presently offers four systems in Honduras: 30 W_p; 40 W_p; 50 W_p; and 60 W_p. To date, all, or nearly all, systems in Honduras use crystalline silicon modules. At present, multi-crystalline technologies (such as that of Evergreen Solar and ASE Americas) are quite common. Thin film technologies such as amorphous silicon have not yet been used[8].

Type of batteries
The USIJI application states that the project would probably employ a mix of 50% automotive lead-acid and 50% deep-cycle lead-acid batteries, based on patterns in the Honduran market at the time. Enersol expected that this would shift to a higher percentage of deep-cycle batteries over time. Systems presently installed in Honduras generally use a mix of automotive lead-acid batteries and longer-lived marine lead-acid batteries. Battery storage capacity typically ranges from 60 to 100 Amp-hours. The USIJI application estimates that 85% of people that obtain SHSs in Honduras previously used car batteries charged at grid-tied shops to power their televisions.

Number and type of lights
The Honduras AIJ project documents do not specify the number or type of lights to be used in the systems. The Soluz operation uses 5-watt and 9-watt compact fluorescent lights. Their 30 Wp system uses 2 lights, the 40 W_p system comes with 3 lights, the 50 W_p system comes with 4 lights, and the 60 W_p system comes with 5 lights.

Other components
In addition to lighting, most of the systems in Honduras power TVs. Nearly all of the Soluz systems do. Radio/cassettes are also common and blenders are used in some cases.

System quality
The USIJI application and subsequent reports discuss the importance of technician training to assure system design and installation quality. As initially conceived, local technicians who had completed at least one Enersol training course covering system design, installation, and maintenance would install the SHSs in the Honduras AIJ project. The USIJI application says that the NGO credit program managers would be careful not to make loans for systems installed by disreputable installers. For its part, Soluz pays careful attention to system quality since the

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[8] (Source: conversation with Richard Hansen on October 4, 2000)

success of its fee-for-service business depends on systems functioning properly. At present, SHS systems in Honduras are not subject to any sort of certification process.

Number of systems installed
The number of SHSs to be installed was not specified in the USIJI application, and subsequent annual reports have varied a bit on this figure. The year 2000 uniform AIJ report to the UNFCCC says that the project will install 2,000 to 7,000 SHSs by 2002 and bases emission reduction projections on the 7,000 figure. The report also states that some 3,000 systems have already been installed in Honduras based on the mechanisms described for the AIJ program, i.e., cash and credit sales enabled by training, technical assistance, and consumer financing initiatives as well as fee-for-service.

B.1.4 SHS market experience in the region

The USIJI application provides some background on SHS project and market experience in the region, focusing on the Dominican Republic and Honduras. Enersol started working in the Dominican Republic in 1984 and opened its Honduran office in 1992. In both cases, the countries had almost no previous SHS installations. In the Dominican Republic, Enersol developed and refined its enterprise development and consumer credit model for solar-based rural electrification. In collaboration with the US Peace Corps, Dominican NGOs, and newly formed small solar home system installation businesses, Enersol conducted market development activities in the Dominican Republic for well over a decade. The same model was employed in Honduras. In both countries, several private sector SHS installation businesses are now active.

In both markets, certain foundations, government agencies, and private investors have supported NGO consumer credit funds and private SHS companies due to their interest in the environment and development benefits of SHSs. This backing has included grants and concessional financing, but direct subsidies to system users have been minimal. Additionally, despite occasional modest government programs in both countries, the marketplace is almost exclusively served by private sector businesses operating in an open and competitive market.

B.2   GHG Sources and System Boundaries

In the Honduras AIJ project, the geographic system boundary was set around individual rural homes. Upstream emissions from the project and the baseline scenarios were considered to cancel each other out, so they were not included in either case. This was stated explicitly in the USIJI application, which cited a World Bank report's analysis demonstrating that upstream emissions for kerosene lighting and solar lanterns cancelled each other out in a proposed GEF project in India.[9] Emissions from the solar home systems themselves were assumed to be zero.

The Honduras USIJI application projected system lifetimes of 20 years based on an expected module life of at least 20 years. Automotive lead-acid batteries were estimated to last 18 months. Deep cycle lead-acid batteries were expected to last 40 months. The automotive and marine lead-acid batteries currently being used reportedly range in life from 1 to 3 years. But, a high percentage of Honduran SHS users had already used car batteries, which tend to last longer with PV charging in an SHS than when charged with grid power.

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9 India Non-Conventional Energy Projects for Global Environment Facility Funding Volume I: Main Report, Prepared by Alternative Energy Development, Inc. for the Global Environment Facility, December 20, 1991.

B.3 Current Rural Energy Situation

Current energy consumption
Based on information contained in the USIJI application, current energy consumption patterns for the Honduran households targeted to participate in AIJ project were estimated to be:

Utility/household	No. of hours/day	Energy source	Monthly or annual energy costs	Monthly energy consumption
Lights		Kerosene		7.57 litres
Radios		Dry cell batteries		8 size D dry cells
TV		Battery charging		5.2 kWh (*)

*) This represents the amount of electricity used to charge a 12 volt, 100 Amp-hour battery that is fully depleted and charged weekly. It applies only to households that charged car batteries prior to obtaining a SHS, estimated in the USIJI application to be 85% of all households.

The USIJI application included information on energy consumption, rather than energy expenditures, as this was more relevant to the questions being asked in the application. Cost figures for energy expenditures are regularly included in GEF project documentation, as this is needed to calculate "incremental costs."

Population density and distance from the grid
Population density and the distance of SHS-using homes from the electric grid were not specified in the AIJ documents for the Honduras project. Richard Hansen estimates that most homes using SHSs in Honduras are from 1 to 25 kilometres from the grid.

The USIJI application and subsequent annual reports say that the Honduras project would target areas where grid extension is unlikely. Furthermore, the documents say "while significant grid extension is not expected, Enersol will maintain contact with the Honduran Planning Ministry and ENEE (Honduran electric company) to assure that solar-based rural electrification efforts do not target communities slated for grid extension, should grid extension plans come into place" (source: year 2000 uniform report to UNFCCC).

Adequacy of current situation
The AIJ project documents refer to several shortcomings in the current rural energy situation in Honduras. For example, kerosene lamps produce a poor quality and quantity of light, pollute indoor air, and are a fire hazard while lugging car batteries to be charged is burdensome. Also, electricity from dry cells costs $30 to $60 per kWh according to Richard Hansen.

B.4 Key Factors Influencing the Project's Impact and/or the Baseline

B.4.1 Project specific factors
Quality of the system
The Honduras AIJ project documents emphasize the importance of appropriate system design, proper installations, and adequate maintenance. These aspects were all included in the technician training workshops conducted by Enersol Associates when it was actively working to develop the SHS market in Honduras. Soluz also places a high value on system quality and maintenance to assure the viability of its fee-for-service operation.

Adequacy of system designs
Soluz offers a product that accommodates a mix of lighting, TV, and radio/cassette usage in accordance with customer demands.

Replacement parts
The mechanisms for system financing in Honduras (cash sales, credit sales requiring a substantial down payment, and fee-for-service, which is presently the principal dissemination vehicle in the AIJ project) indicate that either 1) end-users will probably have the ability and motivation to pay for replacement parts, or 2) parts replacement will be conducted by the fee-for-service company.

System financing and delivery
While the AIJ project documents leave open the possibility for cash and credit sales to be part of the AIJ project, at present the principal activity involves the fee-for-service operation.

Type and level of SHS subsidy
The project does not directly provide subsidies to SHS users. Some NGO consumer credit programs in Honduras have received support from government agencies and foundations as grants or on concessional terms, which has enabled end-users to get loans for SHS purchases even though many of them would not otherwise have access to such credit. For the most part, though, the interest rates charged to end-users have been commercial or near commercial. Similarly, investments in Soluz Inc. and Soluz Honduras have reflected investors' interests in the project's environment and development benefits. This has enabled many households that would not otherwise be able to afford a SHS to obtain service from Soluz. Again, however, direct subsidies to end-users have been negligible.

B.4.2 External Factors

Kerosene subsidies
The AIJ documents do not specify whether, or to what extent, kerosene is subsidized in Honduras.

Grid extension plans
The USIJI application identified grid extension as one possible reason why the anticipated CO_2 benefits from SHSs would not be achieved, but it also indicated that significant grid extension is not expected in Honduras. Furthermore, it explained that the project participants would keep in contact with the national electric utility company to stay informed about grid expansion plans and avoid communities where it might occur. According to Richard Hansen, some grid-extension planning is now underway in Honduras. With the fee-for-service operation, systems could be moved to another service area if grid power came to communities where Soluz was active; however, this could have a considerable cost.

Legal aspects
No legal issues have been identified as barriers to the Honduras AIJ project. Some legal considerations could, however, potentially become important. For example, Honduras plans to eventually privatise its electric power industry. The rules governing the privatised industry could affect private participation in the SHS market. Also, import tariff structures have a big impact. In Honduras, the import duty on PV modules is just 1%.

Socio-economic and demographic developments
The AIJ project documents did not identify any socio-economic and demographic developments that would affect the project. If rural incomes were to increase, this would tend to expand the SHS market by increasing the number of households that could afford to buy an SHS or rent one from the fee-for-service operation.

Other
Natural disasters such as extreme weather can impact the SHS market. For example, Hurricane Mitch hurt some of the small SHS installation businesses in Honduras since the associated loss of crops seriously reduced average income in affected rural areas.

B.5 Baseline Identification and Selection

How many baseline options have been considered
In the USIJI application, Enersol considered only a single baseline: historic energy use. In the most recent uniform AIJ report, the possibility of grid avoidance was also referred to. Prior to the Honduras AIJ project, Enersol had calculated the anticipated CO_2 benefits from SHS use in the Dominican Republic based on grid avoidance. These calculations were made in two different ways: 1) based on the quantity of electricity supplied by a typical SHS; and 2) based on the level of electricity consumption typical for grid-connected rural homes. For the Honduras project, however, only the historic energy baseline was considered.

How was the selection made
At the time the USIJI application was prepared, significant grid extension in Honduras seemed highly unlikely; the historic energy baseline appeared to be the most likely scenario if homes did not get an SHS. The most recent project report to the UNFCCC says: "[i]n the absence of the project, rural household dependence on kerosene lamps for lighting and car batteries for electricity is expected to continue indefinitely."

Do you believe this was an appropriate baseline, and how could it be improved?
The historic energy baseline seems appropriate. The method used to estimate the baseline scenario might potentially be improved. For example, the USIJI application used the figure of average kerosene consumption for lighting in rural homes as the baseline. One study, however, found that roughly 30 percent of about 200 SHS-using Honduran homes surveyed did not use kerosene for lighting prior to obtaining their SHS; most in that category used candles for lighting and some used gasoline generators.[10] This was not anticipated in the baseline, but as explained below, it does not seem to have had much impact on the baseline's ability to accurately estimate anticipated CO_2 saving. Also, the selected baseline did not vary anticipated CO_2 savings based on system size, as has sometimes been done for other projects. This too seems to have been a reasonable approach, as the study referred to above found no correlation between system size and the amount of kerosene previously burned for lighting in rural Honduran homes.[11]

B.6 Estimation of Energy Services Provided

The kWh of energy service supplied from SHSs in Honduras was not estimated in any of the AIJ documents. With an average of approximately 5.5 kWh/m²/day (for a fixed PV array tilted at latitude) assuming a "system factor" of 0.75 to account for efficiency losses, a 50 W_p system in Honduras supplies roughly 6.0 kWh per month on average[12].

B.7 Project Emissions

The AIJ project's CO_2 abatement calculations assumed that there were no emissions from the project itself under the theory that upstream emissions from the project and the baseline should roughly offset each other. Furthermore, no continued kerosene burning was assumed to occur.
The 100% kerosene lighting substitution was probably too optimistic, since some households will probably continue to use some kerosene for outdoor lighting and on occasions where the system battery is fully depleted. While the AIJ project has not yet been officially monitored, household surveys suggest an overall average 94% reduction in kerosene lighting use among rural Honduran households after the installation of an SHS.[13]

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[10] Unpublished 1999 study by Brown University student Maria Reff.

[11] Ibid. The vast majority of households surveyed had systems in the 40-70W_p range.

[12] Source: based on discussions with John Rogers, Vice President of Soluz Inc. Oct. 10, 2000

[13] Op. Cit. Reff (see footnote 3).

B.8   Baseline Emissions

How was the calculation structured?

Enersol used a figure for average kerosene consumption for lighting in unelectrified rural Honduran households, provided in a study prepared for the Honduran Natural Resources Ministry (*Estudio de Sustituciones Energeticos* conducted by the Biomass Technology Group, University of Twente, Netherlands, completed January 15, 1993 corrected March 23, 1993). Additionally, Enersol calculated emissions from battery charging. These two factors, kerosene lighting and battery charging, were both considered part of the baseline, but estimates of CO_2 are based solely on kerosene lighting. The USIJI application explains that was done to be conservative and to simplify monitoring.

What values have been used?

For kerosene consumption: 2 gallons per household per month (i.e., 7.57 litres).

For battery charging: 5.2 kWh per month - representing electricity required to charge a 12 volt, 100 Amp-hour battery that is fully depleted and charged weekly.

In terms of emissions factors, in the annual AIJ reports to the UNFCCC, IPCC figures are used for the carbon content of kerosene; the reports use a factor of 0.00279 t C per gallon of kerosene burned. For battery charging, Enersol used US EPA figures for diesel power plant emissions: 1.25 Kg CO_2 per kWh; the grid-based fuel mix to charge batteries was assumed to be 40% diesel and 60% hydroelectric power based on unpublished projections of the Honduran electricity supply mix for 1994.

Again, while the project has not been formally monitored, survey data indicate that the amount of kerosene used for lighting prior to SHS installations was less than that anticipated in the project baseline -- about 1.6 gallons (i.e., 6 litres) per month rather than 2 gallons per month for households using kerosene for lighting. Furthermore, about 30 percent of SHS-using household surveyed said they did not use kerosene lamps prior to installing their SHS.[14] After accounting for fuel savings from displaced generator use by a portion of the households who did not use kerosene lamps prior to their SHS, however, the overall fuel displacement resulting from SHS installations still averages about 1.6 gallons per household per month overall. Enersol's monitoring plan calls for the baseline assumptions to be confirmed once the project is formally monitored, which should provide further clarification.

The chart below presents a frequency distribution of reported kerosene savings based on survey data from SHS-using Honduran households. As the chart shows, kerosene displacement per household varies widely.

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[14] Op. Cit. Reff (see footnote 3).

Displaced use of kerosene
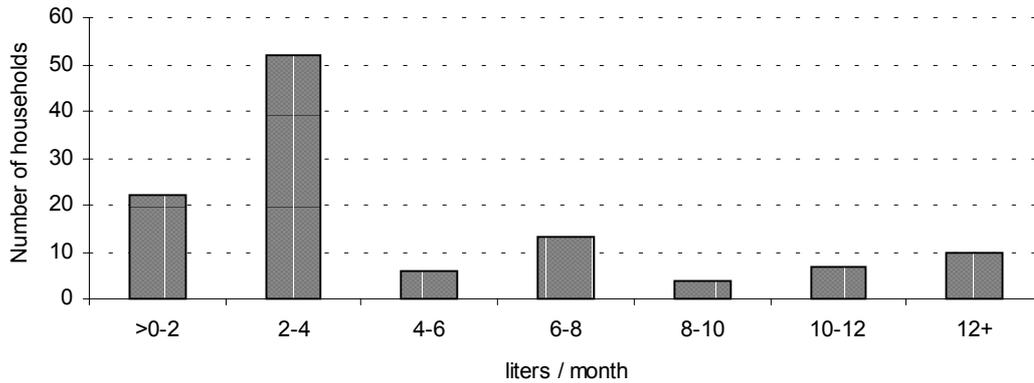
B.9 Crediting Time

The AIJ project documents base emission abatement figures on twenty years of emissions reduction crediting per SHS installation. The 20-year crediting time corresponds with an anticipated 20-year life of the PV modules used in the systems and the assumption that systems will be used over that full time period.

B.10 Estimated Emission Reduction

In the uniform annual reports to the UNFCCC, the AIJ project participants estimate emission reductions of 4.914 tons CO_2 per household over a twenty year period, based on kerosene displacement alone (i.e., not including anticipated emission reductions from displaced battery charging). At present, the project documents indicate that the project is expected to result in 7,000 SHS installations, which will reduce 34,398 tons of CO_2 over 20 years.

B.11 Evaluation of Additionality

Explain why the project would not be undertaken without being a CDM project given both the existing situation (costs, income distribution, technical status of equipment, regulation etc.) and the future situation (planned grid extension, income development etc.)

While the project has not yet benefited from any CER revenues, the environmental motivation of Soluz Honduras's current investors has made the fee-for-service offering possible, increasing system affordability beyond the cash and credit markets. The project's investors clearly value the project in part for its carbon abatement attributes.

In the future, CERs could boost Soluz Honduras's fee-for-service operation through some combination of lowering costs to system users or increasing profitability, which would help to attract additional capital for project expansion.

Confirm that the project would not be undertaken with ODA sources as CDM projects should be additional to ODA

Some GEF funds (via the International Finance Corporation) have been invested in Soluz Honduras' fee-for-service operation, partly as equity and partly as debt financing. This GEF investment could conceivably make Soluz Honduras ineligible to participate in the CDM, although the GEF investment only accounts for a portion of the money invested in its fee-for-service operation. It may be possible to separately account for installations resulting from the GEF's funds specifically, with those installations being deducted from the installations claimed for CDM credit. Depending on the CDM's rules regarding ODA, a portion of another investment might also be ineligible since it may partly have come from Inter-American Development Bank funds.

Conclude on the additionality of the project
The Soluz activity should be considered additional, excluding the IFC investments made with GEF money and possibly some other funds they may be considered ODA. Aside from the ineligible GEF and possible ODA investments, others (e.g., environmentally oriented investors EEAF and E&Co as well as funds from insurance companies concerned about climate change via Sunlight Power) made their investments in part due to the environmental benefits of the activity generally, and the climate change benefits specifically. Investments in the business have not been "business as usual" or mainstream commercial investments.

How do you see this for future projects?
Additionality requirements excluding projects that receive GEF and ODA support will almost certainly be an issue in the case of SHS activities. There are over 20 GEF projects supporting SHS activities in numerous countries, including "global" projects such as the Solar Development Group and PVMTI that are designed to be implemented in multiple countries. Furthermore, several countries have provided bi-lateral development assistance to support projects involving SHS initiatives and other measures for rural energy supply using renewable sources of energy.

It would be unfair and counterproductive to restrict CDM eligibility to only those companies and countries that have never received GEF or ODA support to initiate or stimulate SHS activities. The simplest approach to excluding SHS activities benefiting from GEF and ODA funds would be to require that no SHS installation be eligible for CERs if it has been directly financed with GEF or ODA funds.

India

Dr Alison Hunt with Dr John Green and Dr Jonathan Bates
IT Power, UK

SUMMARY

PV companies in India (and Sri Lanka) have recently benefited from a $500 000 grant for credit financing of Solar Home Systems (SHSs). These funds have arisen from a carbon offset package from the US-based Klamath Falls Cogeneration Project. The package was put together by the power company, PacifiCorp Power Marketing, Inc, in order to win approval for its proposed 500 MW power plant in Oregon, US. Baseline calculations for CO_2 mitigation were carried out by Mark Trexler Associates as part of the justification for the power plant. This case study draws heavily on the published 'Order' that came before the State of Oregon Energy Facility Siting Council. The baseline calculations in the Order were carried out using generic figures rather country specific data. This case study attempts to assess the validity of these calculations, with a format based upon a questionnaire devised by ECN and commented upon by IT Power and Sunrise Technologies Consulting.

C. INDIA

C.1 Project characteristics

C.1.1 General project information

A grant of US$500 000 has been provided by the Klamath Cogeneration Project in Oregon (US) for PV companies in India and Sri Lanka to finance credit sales of Solar Home Systems (SHSs). It is the world's first commercial carbon offset funding agreement for solar rural electrification. Over a 30 year period, a total of 182,000 SHSs are expected to be installed in India and Sri Lanka which will result in estimated CO_2 emission reductions of 1.36 million tonnes. No breakdown of the number of systems to be installed in the two countries is given.

The agreement was signed in September 1999 by the Solar Electric Light Company (SELCO) and the Solar Energy Trust, with US$500 000 from the Klamath Cogeneration Project, a joint development of PacifiCorp Power Marketing, Inc. and the City of Klamath Falls, Oregon. The Klamath Cogeneration Project - a 500 MW gas-fired power plant - was approved on the basis of its carbon offset portfolio. The portfolio has a total value of US$5.5 million for carbon offset projects designed to reduce or sequester carbon.

Dr Mark Trexler of Trexler and Associates Inc put together the offset portfolio on contract to Klamath. They used guidelines established by U.S. DOE under Section 1605(b) of the EPAct. U.S. DOE, Voluntary Reporting of Greenhouse Gases under Section 1605(b) of the Energy Policy Act of 1992 – General Guidelines (1994).

Three documents were drawn heavily upon for this case study: the Order[15], the Klamath Cogeneration Plant Requests[16] and Klamath Cogeneration Plant Testimony[17].

The original Order mentioned installations in India, Sri Lanka and China. However it has since been decided that installations will only take place in India and Sri Lanka. In India, SELCO Photovoltaic Electrification (P) Ltd. ("SELCO India") will manage the project. SELCO is the majority shareholder of SELCO India. In Sri Lanka, RESCO Asia Ltd. ("RESCO") is managing the project.

This case study examines the baseline calculations for India as opposed to Sri Lanka, as more published data is available for India.

N.B. A USIJI document exists[18] which details a project in Sri Lanka which will install 812 000 SHS over 10 years leading to 5 684 488 tonnes of CO_2 benefits over the project's 29 year lifetime. The document mentions the same partners as in *this* case study, but according to SELCO this project exists only on paper and is not an actual project. *Details of it will therefore not be included in this study.*

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[15] *Order*: "In the matter of the 500 Megawatt Exemption from the Demonstration of Showing Need for a Power Plant" (Before the STATE OF OREGON ENERGY FACILITY SITING COUNCIL)

[16] KG Requests, excerpts of which are available from the Oregon Office of Energy

[17] KG rebuttal testimony in the name of Mark Trexler, excerpts of which are available from the Oregon Office of Energy

[18] Downloadable from the UNFCCC Web site.

C.1.2 Objective(s) of the project

The overall objective of the project is the reduction of CO_2 emissions through reduced consumption of kerosene for domestic lighting and reduced use of diesel generators for battery recharging. The objective will be achieved by providing funds to increase the number of sales of SHSs.

C.1.3 Description of the SHS(s) used in the project

System Size
Baseline calculations in the Order were calculated on a mix of system sizes: 10% 20 W_p and 90% 35W_p[19].

Type of Panel
The type of PV panel is not specified but SELCO India commonly uses Tata-BP Solar panels.

Quality of the Systems
Quality is a priority issue of SELCO India and they guarantee their modules for 10 years. There is no explicit mention of certification of system components.

Type of Battery
SELCO India provides deep-cycle batteries purchased on the Indian market.

Number and Type of Lights
According to the Order, the 20 W_p systems will have three 8 W compact fluorescent lights (CFLs) and the 35 W_p systems have four 8 W CFLs or two 11 W CFLs. The number of lights for the 20W_p systems seem to be optimistic. Another source[20] states that SELCO's 20W_p systems supply enough power for just one 11W light or two 7W lights.

SELCO India manufactures it's own lights and charge controllers.

Other Components
According to the Order, the 20 W_p systems will also provide power for radio/cassette player whereas 35 W_p systems are designed to also provide power for a 12 V DC black-and-white television set.

Number of SHS installed
The project intends to install 182 000 SHSs over 30 years.

An overview of SHS project and market experience in the region to put SHS activities into context
Information is given on SELCO projects since they have been high profile in India.

SELCO India was established in 1995 and is an outgrowth of the Solar Electric Light Fund (SELF), an international development organisation that pioneered the use of SHSs. It has its headquarters in Bangalore and branches in Mangalore and Manipal. It also has a total of ten Solar Service Centres which provide installation and servicing of SHSs throughout Southern India.

Grid electricity has expanded rapidly in India to cover 90% of the country but the quality of power is often very poor, and frequently unavailable for long periods of the day. In addition to this, connection rates are very low with the result that 65-70% of the population are without

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[19] Page 34, KG Request

[20] Private correspondence with Binu Parthan, IT Power India

grid-electricity. This situation arises from prohibitively high connection charges for some customers and poor power availability.

The solar regime in India is very good, with an average insolation of $5.6 kWh/m^2/day$.

C.2 Description and determination of GHG sources and system boundaries

This information is covered in later sections.

C.3 Current situation

C.3.1 Energy use and expenditures of the households

In the first year it is intended[21] to install 2 000 systems in both India and Sri Lanka, though no information was supplied about the breakdown of the number of systems in each country. This target looks likely to be met. Specific householder information is not known since the installations are at an early stage and are commercially sensitive according to SELCO. From the KG Request[22] it is stated that between US$7 and US$10 per month is spent on kerosene and dry-cell batteries for flashlights and radios by rural households. The actual country upon which these figures are based is not specified.

According to SELCO India's Web site [23] there are "millions" of households that spend Rs. 400 (US$8.6) per month on kerosene, candles and dry-cells and car battery recharging. Also, they estimate that "in Karnataka, Andhra Pradesh, Kerala, and Tamil Nadu alone there are an estimated 400 000 farms, rural shops, banks, cooperatives, restaurants, and other small enterprises for whom low-cost solar PV systems can be economically productive".

It is the experience of SELCO India[24] that a proportion of clients are able to pay for the systems up front. If not, then a large number are able to pay on 90 day credit terms. However, most people would require extended credit terms (over three years). The extended terms are 25% deposit followed by interest payable at 13%. Average monthly payments are between US$8 and US$12 depending on the system size.

A recent report publicising kerosene use in households installed with SHSs[25] had average kerosene use per household (prior to system installation) of around 10 litres/month.

Distance to Grid/Population Density
No meaningful information for distance to grid or population density is given since the installation sites have not been determined and these parameters would vary considerably between sites. However, it *is* the case that a large proportion of India's villages have been electrified i.e. an electricity grid is located close to most populations. Having said this the connection rate is very low as mentioned earlier and the quality of the power is very poor. Daily power outages of 20 hours a day for rural areas are quoted[26]. In these situations SHSs might provide the only firm power[27].

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[21] Private correspondence with Larry LaFranchi, SELCO

[22] Page 3-29, KG Request

[23] www.selco-india.com

[24] RSVP Project 165

[25] Ramakrishna Mission Initiative Impact Study: Monthly Technical Progress report No. 1, January 2000

[26] www.self.org/india.asp

[27] Page 80, Rebuttal testimony of Dr Mark C Trexler

C.4 Key factors, influencing the project impact and/or the baseline

C.4.1 Project specific factors

Adequacy of system design to users' preferences
No information is available on this but it is likely that a 35 Wp system with enough power for four 8 W CFLs and a black and white television would go a major way to reducing kerosene use and diesel powered battery recharging.

Quality of installations
SELCO India focuses on providing reliable electric service to its customers. It does this by using their own trained installers.

Maintenance
SELCO India has a network of solar service centres and service technicians. They provide after sales service for one year via periodic maintenance checks with further instructions provided as necessary.

Adjustments and replacements of spare parts
No information is given on this. It is probably the case that the householder would have to pay for these as and when required. It is important therefore for the householder to be made aware of potential future costs of the system, otherwise the system may become inoperable through lack of funds to replace parts. This is particularly true for the battery which may need replacing every four years and is a significant expense, costing around 20% of the total system costs. If the system becomes inoperable, it will obviously lose its ability to mitigate carbon.

Is theft an issue?
Two out of 300 systems installed were reported stolen in the 1999 Ramakrishna Mission report[25].

Type of financing and delivery mechanisms used (cash sales, credit sales, fee-for-service)
The finance is provided through a Revolving Investment Fund (RIF). The Klamath Cogeneration Project has provided US$500 000 for zero interest equity loans to PV companies in India and Sri Lanka (SELCO and RESCO respectively).

In India, SELCO will use the funds to guarantee a loan or credit line with financial institutions who will lend to the purchasers. This method of financing the systems will reduce the interest rates applied and will enable the customers to pay back the loan in one rather than three years.

Type and level/percentage of SHS subsidy (i.e., equipment "buy-down", interest rate subsidy, etc.)
As mentioned, the payment period is hoped to be reduced to one year, but no information about interest rate payable for customers is available. SELCO's normal operation is 3 years at 13%.

Satisfaction of the end-users about the system and income (factors that determine whether end-users are willing to pay for SHS services).
Only anecdotal information available, as mentioned earlier[23].

C.4.2 External Factors

Kerosene Subsidies
Not known.

Income Development
No information is available at this stage for these particular installations.

Plans for Grid Extensions
As previously mentioned the grid does already cover the majority of the country but connection rates are very low due to connection charges and poor power supply. Grid extension therefore is not an issue, but increasing grid connection is a factor which could possibly influence the validity of installing PV systems. It might for example be more cost effective to subsidise grid connection charges rather than provide credit funds for SHSs. However, the poor availability of power would still be a major barrier to widespread grid electrification of the population.

Legal aspects
Not known.

Socio-economic developments
In Pavur, Kerala, India where each house was installed with two solar lights a report[28] found improved health, better conditions for children to study in, more children paid to go to school and that men drunk less in the evening due to more productive activities.

Demographic developments
Not known.

C.5 Identification of baselines and selection of most likely baselines

How many baseline options have been considered?
Only one baseline was considered – the CO_2 emissions of the households' emissions from direct burning of kerosene for lighting, and emissions associated with generating electricity for battery recharging prior to installation of SHSs.

Do you believe this was an appropriate baseline, and how could it be improved?
Whilst the baseline may be appropriate, the figures on which it is based are open to question. A recent report publicising kerosene use in households installed with SHSs[25] gives reduction in kerosene use of 6.33 litres/month. Using a conversion factor of 2.55 kg CO_2/litre kerosene (implied in the Order), this would give an annual average CO_2 reduction for each system of 0.194 tonnes. This figure is around half the amount calculated in the Order (0.344 tonnes). There is the possibility that the SHSs surveyed for the report had low initial energy use when compared with an assumed average figure for India/Sri Lanka/China that may have been used as the generic figure in the Order. However, there is the strong possibility that residual kerosene use is much higher than the 2% anticipated. For this reason, the figures for CO_2 reductions given in the Order are possibly over-estimated.

C.6 Estimation of energy services provided

Estimate of the energy services that will be delivered by the SHS and its development over the time.
The services consist of lighting and spare capacity for either a radio or TV. The energy available for the additional appliances (from the remaining 15 W remaining after the 20 W for the lighting) were estimated[29]: for the 35 W_p systems operating for 5.5 hours per day, 30 kWh of energy would be generated per year. The total energy is not stated. This value of 30 kWh per year for additional appliances alone is on the high side. In India it would be expected that a 35W_p system would generate around 40 kWh/yr. A utilisation factor of around 65% would reduce the total power availability to around 26 kWh/yr. This would be the total amount available for lighting *and* additional appliances.

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[28] "Women are a Major Factor in the Success of One Indian Village", REPSource (The Newsletter of the International Network of Renewable Project Support Offices), Vol 4, No.1.

[29] Page 3-33, KG Request

A system lifetime of 20 years is assumed. It is further assumed[30] that the CO_2 benefits per system will not change over the lifetime of the system.

C.7   Project Emissions

How has a Life Cycle Analysis been carried out - what were the assumptions?
According to answers given by Mark Trexler[31], CO_2 emission estimates for the manufacture of PV panels are about 10% of the total CO_2 offsets from using SHSs. They state that this would be cancelled out by up-stream emissions from refining and transporting kerosene.

It is expected that the battery would be recycled at the end of its useful life[32]. No justifications for this are given. In addition, no mention is made of the need to replace batteries on a regular basis. Over a 20 year period a minimum of five batteries would be required.

Is kerosene lighting expected to continue once the SHSs are installed. If so, how much?
Kerosene consumption is expected to contribute less than two percent of total lighting needs. For 20 W_p systems and larger, the emissions would be responsible for 0.0069 tonnes[33] CO_2 per year. As stated before the two percent emissions seems optimistic. Information from India[34] suggests that kerosene consumption for lighting would continue despite the installation of SHSs to meet the needs for portable lights, lighting in rooms which have no CFLs and more occasionally for special occasions such as festivals, marriages, birthdays etc. where pressurised kerosene lamps with a mantle are used (usually hired).

C.8   Baseline Emissions

How was the calculation structured?
The baseline emissions include those from kerosene lamps and from battery charging. It also takes into account the fact that different system sizes will be installed.

Kerosene use

It is assumed that three lights (3 x 8 W) are used which displace a total of 0.344 tonnes CO_2 per year. This is the case for both the 20 W_p and 35 W_p systems.

Battery recharging

The 35 W_p systems also displace emissions attributable to battery recharging (which currently takes place for running electric appliances such as TVs and radios). It is assumed that 15 W of the 35 W would be used to mitigate these emissions. This additional amount is equal to 0.031 tonnes per year. For a weighted average of 10% 20 W_p systems and 90% 35 W_p systems the battery charging emissions are 0.028 tonnes per year.

Combined emissions

The combination of kerosene and battery charging emissions is therefore 0.373 tonnes per year for each system.

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[30] Page 3-34, KG Request
[31] Page 78, Rebuttal testimony of Dr Mark C Trexler
[32] Page 78, Rebuttal testimony of Dr Mark C Trexler
[33] All measurements in the Order are in Imperial units i.e. tons. For the purpose of this case study they have all been converted to metric tonnes (1 ton = 1.016 tonnes, US gallon = 3.785 litres, 1 lb = 0.4536 kg)
[34] Private correspondence, Binu Parthan, IT Power India

The installation of SHSs is expected to follow a roughly exponential curve[35] with around 1 000 systems installed per year in the first five years, 5 000 systems per year in year 17, 10 000 per year in year 22 and 23 000 per year in the thirtieth year.

What values have been used?
There is some confusion over the values that have been used in the calculations. The Order states that "each 8 W light displaces a kerosene lamp that consumes approximately 10.6 gallons of kerosene per year which, based on the carbon content of kerosene, is responsible for 226 lbs of CO_2 emissions annually". However, if these figures are used, the subsequent figures do not tally. Working back from the final figures leads to a figure of 253 lbs or 113 kg CO_2 per kerosene lamp.

CO_2 emissions for coal are assumed to be 1.07 tonnes per MWh ("conservative assumptions of a heat rate of 10 000 Btu/kWh and coal with a heat content of 10 000 Btu/lb. and a 57 percent carbon content").

C.9   Determination of crediting time

What lifetime and crediting time were applied?
The crediting time is given a limit of 30 years. Each system is expected to last 20 years. No mention is made of the need to replace systems batteries before that time, though 80% of households are expected to replace their panels after 20 years.

C.10   Estimation of the emission reduction

Each year, the average system will displace a constant 373 kg of CO_2 which over its 20 year lifetime will displace more than 7.46 tonnes of CO_2. Carbon dioxide emissions totalling 1.36 million tonnes will be avoided as a result of the project.

C.11   Evaluation of Additionality

Explain why the project would not be undertaken without being a CDM project given both the existing situation (costs, income distribution, technical status of equipment, regulation etc.) and the future situation (planned grid extension, income development etc.)

For householders seeking to solve their power supply problems it is often difficult to acquire credit facilities to obtain SHSs.

Grid extensions are notoriously expensive. A figure of US$4 500/km for grid extensions in developing countries was quoted[36] which makes it prohibitively expensive to extend the grid into rural (and possibly sparsely populated regions). Where the grid extends to a region the quality of power can be extremely poor with either regular (or irregular) load shedding or low voltage problems. Another basic problem is that demand outstrips supply in many rural networks in India.

Confirm that the project would not be undertaken with ODA sources as CDM projects should be additional to ODA
Without a financial support mechanism such as that provided by the Klamath project, or subsidies, the number of SHS being installed in India will be restricted due to the difficulty in purchasers

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[35] Figure 3-1, KG Request
[36] Page 80, Rebuttal testimony of Dr Mark C Trexler

obtaining credit from lenders. This type of carbon offset project may become eligible for support under the CDM, in which case it will possible to demonstrate additionality as shown above.

Conclude on the additionality of the projects
One potential complication that must be addressed is what happens when systems are purchased by people who are grid connected. Their motivation for purchasing the SHSs are that the grid provides electricity for only a few hours a day, and that at low voltage. In India[37] they then use the SHS as the primary lighting source, with grid power as a backup and for running the colour TV etc. Security is also a driver since PV systems give firm power during power outages which decreases the chance of thieves striking – this is apparently a prime time to be the victim of crime.

In these cases the introduction of SHSs may have a marginal impact on emission reductions. It would be important to study the effect of previous installations in an area (for all social groups) before making judgements about how the systems would be used and whether there would be any environmental additionality.

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[37] Conversation with Kamal Kapadia, Solar Electric Light Company, 18th October 2000.

Indonesia

F.D.J. Nieuwenhout

SUMMARY

This case study describes the solar home system component of World Bank/GEF project in Indonesia. In addition some information on other sources is presented, mainly of the demonstration project in Sukatani. The World Bank Staff Appraisal Report "Indonesia Solar Home Systems Project"[1] provides the basic information on which the project has been designed. It has been used extensively in this case study. When no explicit other sources are mentioned, information is cited from this report. Monitoring of the project is planned. Implementation was delayed due to the financial crisis in the region. CO_2 abatement is expected of 448 kg CO_2 per solar home system per year.

D. INDONESIA

D.1 Project characteristics

Objectives
The project is meant to assist market penetration of solar PV systems in a nearly commercial market. By creating a potential market with a critical mass, the way is paved for a accelerated introduction of solar home systems. The lending programme will support a series of linked projects over time, where each will build on the lessons learnt from the predecessor project. National objectives are to: (i) Provide modern energy to customers that cannot be served economically by conventional rural electrification, (ii) facilitate participation of the private sector, (iii) promote environmentally sound energy resource development in Indonesia, and (iv) strengthen Indonesia's institutional capacity.

Global objective of the project is to mitigate emission of CO_2 in Indonesia. The project will displace 1.3 million tonnes of CO_2 directly and has an additional indirect "programmatic effect" of 0.9 million tons.

Financing
Credit will be provided for 200,000 solar home systems with an average of 50 Wp per system. Target groups are households and commercial establishments such as small shops. The sales of solar home systems will be by private enterprises. Credit is supposed to be provided through the dealer, who would bear the collection risk for customer payments. A GEF grant of US$ 75 will be provided to dealer for each unit installed in Java and US$ 125 per unit outside Java. The dealers will obtain access to credit via participating banks.

D.1.1 Description of the SHS used in the project

Type of module
Units sold under this project have PV-modules with an output of at least 50 Wp. Modules must be certified, and thin film modules are allowed. Before project implementation started some of the original requirements were relaxed. Also systems smaller than 50 Wp can now be included.

Type of batteries
The 12 Volt battery has minimum capacity of 70 Ah resulting in an autonomy of three days. Auto-motive batteries are allowed but need to meet the Indonesian Standard SII 0160-77 and must have a specified minimum plate thickness. A battery charge regulator is used which has to comply with a number of safety requirements.

Number and type of lights
At least three fluorescent light fixtures are required. A minimum lighting level and efficiency of the lights are specified.

Quality
Detailed requirements for the solar home system components have been formulated with BPPT, the Indonesian PV trade association and international experts. All equipment and components used in this project must be certified. This is supposed to guarantee a minimum level of quality. Recently, BPPT's solar energy laboratory at LSDE received ISO Guide 25 status for certifying solar home system components.

Number of SHS installed

Implementation of the project was severely delayed due to the financial crisis that hit Indonesia in 1997. Early 2000 only one dealer was certified to deliver under the project and only few hundred systems were distributed. In earlier projects, about 80,000 systems have been installed in Indonesia until early 2000, according to BPPT.

SHS market experience in Indonesia

Solar home systems have been introduced in Indonesia in a demonstration project in Sukatani, which was inaugurated by the president. As a follow-up activity, the presidential support project *Banpres* provided about 3500 households with solar home systems. Distribution was via village cooperatives. The success of Banpres and other projects resulted in the formulation of an ambitious 50 MW government programme, aimed at reaching one million households within 10 years. The GEF/World Bank "Indonesia Solar Home Systems Project " is one of the current activities in this programme.

D.2   Greenhouse gas sources and sinks and system boundaries

In the Staff Appraisal Report it was assumed that:
1. There are no CO_2 emissions related to the solar home system units, resulting in a total replacement of the fossil fuel use that would have taken place under the baseline scenario.
2. The lifetime of the systems were assumed to be 15 years.
3. No explicit component lifetimes were given, but the battery lifetime was inferred to be 4 years

These assumptions imply that the system boundary is the individual household. No explicit reasoning of this assumption was found in the Staff Appraisal Report.

D.3   Description of current delivery system

Rural electrification in Indonesia is lagging behind neighbouring countries. Only 40% of rural households have access to grid electricity. Village electrification varies from 32% in Kalimantan to 87% on Java.

Target areas for the project are located in three provinces (West Java, Lampung and South Sulawesi), in areas where the electricity utility is not expected to extent the grid in the coming three years under the Rural Electrification Master Plan.

In Indonesia today, isolated rural households use kerosene lamps for lighting and automobile batteries for other lighting needs. These are charged at diesel based generating stations. Electricity supply is not available in the medium term. The baseline course of action is that these households will continue to rely on fossil fuels.

Based on survey data, the monthly economic expenditures of the target households on kerosene and battery charging are US$ 9.32 on Java and US$ 9.99 off-Java. Over a period of 15 year this results in discounted household expenditures of US$ 867 on Java and US$ 930 off-Java with a discount rate of 10% [1]

Based on the CO_2 emission calculation presented in Annex 3.6 of the Staff Appraisal Report, it can be calculated that the 62 kWh of electricity generated in a solar home system each year, saves 434 kg of CO_2 due to kerosene substitution. This is equivalent to 172 litres per year.

According to an analysis of BPPT in Sukatani [2], the use of three different kerosene lamps decreased with 49.5% in case of the lampu centir, 44% for the lampu tempel and 64% reduction in case of the petromax. Remaining kerosene lamps are used when the battery is empty or it is used in rooms without electric light. Average kerosene use for lighting decreased from 23,67

litres per month to 6 litres after introduction of the solar home systems. Average savings amounted to Rp. 3.975 per month, which is 6.3% of average monthly expenditures of Rp. 91.332. (the exchange rate in 1988 was Rp 1712 per US$). Annual kerosene savings at 212 litres per year are about 25% higher than assumed in the analysis for the World Bank project. This can be due to the higher than average income levels in Sukatani.

A subdivision was made into two groups of households based on energy consumption before introduction of the solar home system: one that used only kerosene for lighting and the other that used both kerosene for lighting and car batteries for electric appliances. 58% of the households only used kerosene for lighting. Average savings on kerosene was Rp3.737. This is 4.37% of monthly household expenditures of Rp. 85.468. Households that had battery charging and kerosene had average kerosene savings of Rp 4.354, and savings on battery charging and transport of Rp. 3.875. As expected, household expenditure levels in this category are higher: Rp. 99.670 per month.

For those households that were used to having batteries charged elsewhere, the reported saving were Rp. 3.819 per month, equivalent to 4.18% of average expenditures. Savings in dry cell batteries were not recorded due to inavailability of adapters for radio's and cassette players. [2]

An earlier BBPT report [3] focuses on the socio-economic situation in Sukatani before the introduction of solar electricity. Per capita expenditure levels were Rp. 204.820 per year, which substantially above the minimum standards of need of Rp. 118.400 per year. Energy expenditures were Rp 122.183 per household per year. A break-down is provided in table 1

Table 1. Average household energy expenditures in Sukatani in 1988

Service	Energy source	annual energy costs [US$/yr]
Lighting	Kerosene	35.98
Cooking	Firewood	17.15
Radio cassette (lighting)	Dry-cell batteries	8.76
Ironing	Charcoal	1.22
Television	Car batteries	8.26
Total		71.37

Source: Komarudin et al, 1988 [3] (exchange rate used: 1712 Rp = 1 US$

The following figures can be calculated based on the information provided in the BPPT report [3]. In 42% of the households, batteries were in use before the introduction of solar home systems. This implies a cost of batteries for users of US$ 19.66 per household per year. Radio cassette players are in use in 60% of the households, implying dry cell battery costs of US$ 14.60 per using household per year.

Almost all (98%) households use wood for cooking. When assuming that all kerosene is used for lighting, and using an kerosene price of Rp. 225 per litre, kerosene consumption amounts to 274 litres per household per year. [3]

D.4   Key factors influencing the baseline and the project

D.4.1 Project specific factors

Delivery mode
The systems will be distributed through a credit scheme. Local dealers of SHS play an important role in project implementation. Dealers are responsible for collecting the instalment payments. On their turn, SHS dealers can obtain credit from commercial banks for up to five years. 80% of these bank loans can be refinanced through a World Bank credit of US$ 20 million.

Quality of the system
Specifications and requirements for components of solar home systems have been formulated. BPPT staff have been trained to test equipment, and the BPPT-LSDE laboratory is one of the few laboratories in the world that are ISO Guide 25 certified for conducting SHS component tests. It is expected that these requirements guarantee a minimum quality level.

Adequacy of system design to users' preferences
Three lights and at least one power point are provided. Experiences elsewhere show that this is sufficient to replace a major part of the kerosene use for lighting, and allow for a few hours radio or low-wattage television.

Solar home systems have standardised sizes, and in many projects only a single module size is possible. However, energy demand is different from household to household. It is possible that not all available energy in a solar home system is actually used, because of full batteries during daytime. For the relatively large (80 Wp) systems in Sukatani, it was found that 15% of the energy available energy from the module cannot be fed into the battery because of full batteries [4].

The amount of electricity available for use is influenced by the system losses. Reinders et al were able to analyse these losses for one the systems in Sukatani. Total losses amount to 48%. [4] This includes the above mentioned loss due to full batteries, but excludes losses due to dust on the module and shading. These figures support a choice of 50% for the system factor. [ECN]
Quality of installation and maintenance
To become eligible for project support, dealers must offer customer protection in the form of warranties and after-sales services. It is not explicitly mentioned in the Staff Appraisal Report, this probably implies that the systems will be installed through the dealer.

Replacement of components
The dealers are free to choose a participating bank that provides the credit that they can onlend to their customers. It is therefore not clear if provisions will be made for households to borrow money for replacement parts. However, since there will be full cost recovery, except for the 75-125 US$ GEF grant, people will get used to the regular fee, making the cost of replacing the battery acceptable.

Theft
Nothing is mentioned about theft.

Change of ownership
In the evaluation of Sukatani it was found that in 34% of the cases ownership of the solar home systems has changed over the 9-year period.[4]

Type and level of SHS subsidies
Cost levels of solar home systems differ from region to region. Java island has the most developed infrastructure, resulting in the lowest costs. Initial system costs are US$ 636 on Java and US$ 750 elsewhere. The present value of the replacements over a fifteen year period are estimated at US$ 304 for Java and US$ 309 elsewhere. This results in present values (at 10% discount rate) of US$ 940 on Java and US$ 1059 in the rest of Indonesia. For the environmental benefits a GEF subsidy is provided of US$ 75 on Java (equivalent to 8% of total present value) and US$ 125 outside Java (equivalent to 12%).

D.4.2 External Factors

Kerosene subsidies
Kerosene is heavily subsidised in Indonesia. In 1988 the retail price of kerosene was only US$ 0.13 per litre. Abolishing the kerosene subsidies will be beneficial for project implementation due to increased cost of the alternatives. However, kerosene consumption for lighting can be expected to decline when subsidies will be decreased or completely abolished.

grid extension
A decentralised rural electrification (DRE) plan will be formulated that will have a niche focussing on the market for solar home systems. The DRE plan will consider a variety of options and develop a 10-year implementation plan for SHS. This will reduce the chance of possible conflicts with grid extension plans.

D.5   Selection of the most likely baseline

The baseline used in the World Bank project was applying historic energy use, and assuming that this level will be constant over a period of 15 years

D.6   Estimation of energy services provided

A typical 50 Wp solar home system in Indonesia will generate about 170 Wh of useful energy per day, based on 3.4 hours of sunshine per day. This is sufficient to provide power for three fluorescent lights and a small black and white television set for about five hours per day. A comparable level of services is provided to rural household connected to the electricity grid. They consume about 15 kWh per month, but are using inefficient incandescent light bulbs.

The calculation of useful energy available in a SHS in the World Bank and E7 projects do not take into account the system losses. These are in the order of 50%, greatly reducing the available energy. However, since the calculated CO_2 savings are based on replaced kerosene and battery charging, the assumed absence of system losses do not affect the CO_2 savings per solar home system.

D.7   Estimation of project emissions

In the calculation of the global environmental benefits in the Staff Appraisal Report, a number of implicit assumptions have been made:
a) A solar home system replaces a fixed amount of alternative fossil fuel sources, which does not develop over time
b) There is no partial or complete system failure over the period of 15 year over which the CO_2 abatement has been calculated;
c) CO_2 emissions in production and transport of the SHS have not been taken into account in the project emissions.
Consequently, the direct project emissions are assumed to be 0.

Due to implementation of the project, an acceleration of SHS market penetration in Indonesia is expected. This "programmatic effect" is assumed to result in avoided emissions of 0.9 million tonnes of CO_2 as a result of the project.

No explicit information about lifetimes of components could be found in the Staff Appraisal Report. A table on Economic Cost Benefit Analysis (Annex 4.2) shows the start of substantial replacement costs in the fifth year of the project. Since battery replacement dominates the replacement costs it can be inferred that the assumed lifetime of the battery is four years.

Battery lifetimes of 3.5 to 4 years were also obtained in the analysis of Sukatani data [4]. This source mentioned replacement of 11 out of 62 charge regulators over a period of nine years. This is in accordance with a charge regulator lifetime of 10 years.

D.8   Estimation of baseline emissions

In the Staff Appraisal Report, only one baseline has been chosen. Data on energy consumption figures come from previous household surveys. The calculation of energy and CO_2 savings per unit starts with assuming that a 50 W_p SHS unit generates 170 Wh per day, 62 kWh per year or 931 kWh over 15 years (undiscounted). To calculate the emissions from the substitute technologies, the following emission factors are assumed: 10,000 tonnes[38] of CO_2 per GWh equivalent for kerosene lighting and 1,100 tonnes of CO_2 per GWh-equivalent for diesel-based battery charging. The weighted average of the substitute technologies is assumed to be 70% for kerosene lighting, 20% for battery charging with the remaining 10% is associated with zero emissions. This results in a weighted average of 7,220 tonnes of CO_2 per GWh equivalent. By multiplying with 931 kWh this results in undiscounted CO_2 emission reduction of 6.72 tons of CO_2 per solar home system. 200,000 solar home systems result in 1.3 million tonnes of avoided emissions. The acceleration of SHS market penetration in Indonesia as a result of the project is assumed to provide an additional savings of 0.9 million ton of CO_2.

In the E7 project, larger quantities of kerosene savings have been assumed of 197 litres per year. With a carbon content of 2.545 kg CO_2 per litre this results in 502 kg CO_2 for kerosene substitution, and an additional 21 kg for savings on diesel generated electricity. Over the evaluation period of ten years this results in savings of 5.22 tonnes of CO_2 per SHS. Betz also discusses two alternative scenarios with annual CO_2 savings of 265 and 407 kg CO_2 per year. In the scenario with the lowest savings, lower kerosene consumption levels have been taken (126.4 l/y). Furthermore, based on experiences in Nepal a remaining kerosene use is assumed of 20%. [5].

D.9   Crediting time

Crediting time used in this World Bank - GEF project is 15 years.

D.10   Estimation of the emission reduction

Direct displacement of CO_2 due to complete implementation of the project (200,000 SHS of 50 Wp) displaces 1.3 million tonnes of CO_2. Additional "programmatic" effects (additional sales not within the project, but due to the improved infrastructure and other externalities) are 0.9 million tons, resulting in a total abatement of 2.2 million tons.

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[38] One tonne is 1,000 kilogram.

D.11 Evaluation of the additionality

The Staff Appraisal Project provides the documentation to calculate incremental costs levels. In new areas on Java the cost for continued use of fossil fuels over a period of 15 years is US$ 867 per household. Cost of the solar home system alternative is US$ 940, resulting in an incremental cost of US$ 73. Outside Java the baseline cost is US$ 930 compared to the alternative cost of US$ 1059, implying incremental costs of US$ 129 per SHS unit. With 200,000 solar home systems equally divided over Java and elsewhere, the total incremental costs for the SHS units amount to US$ 20 million. Another 4 million of GEF grant support is for the Project Support Group, and institutional strengthening of BPPT. With a direct project effect of 1.3 million tonnes of CO_2 savings, the GEF unit cost is about US 18 per ton.

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[1] The World Bank, Staff Appraisal Report, Indonesia Solar Home System Project, December 17, 1996

[2] Komarudin MA et al., Analisa dampak sosial ekonomi dan budaya dalam rangka pengkajian dan penerapan pembangkit listrik tenaga surya (PLTS) di desa Sukatani (socio-economic and cultural impact analysis on the implementation of solar electric generators in Sukatani), BPPT, 1989.

[3] Komarudin MA, et al., Studi sosial ekonomi dalam rangka penerapan teknologi surya di desa Sukatani, (socio-economic study on the implementation of solar energy in Sukatani), BPPT, 1988.

[4] Reinders, A.H.M.E. , Pramusito, A. Sudradjat, V.A.P. van Dijk, R. Mulyadi, W.C. Turkenburg, Sukatani revisited: on the performance of nine-year old solar home systems and street lighting systems in Indonesia, Renewable and Sustainable Energy Reviews, 3 (1999) 1-47.

[5] Betz, Regina, The Activities Implemented Jointly (AIJ) Project of the E7 Initiative: Renewable Energy Supply Systems in Indonesia, A case study, ISI Working Paper, Karlsruhe, February 1999.

Nepal

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SUMMARY

Nepal is one of the poorest countries of the world in terms of its GDP per capita and its fuel use. In rural Nepal households generally rely on kerosene and candles for lighting, dry cell batteries for radios and cassette players and wood for cooking. Solar Home Systems (SHSs) have recently been introduced in Nepal but have generally been available only to the wealthier members of society due to their prohibitively high capital costs. In theory the SHSs provide enough energy to displace the traditional fossil fuel based energy used for lighting and radio/cassettes. The level of displacement is not well documented but this case study endeavours to shed some light on how energy use has changed following installation of SHSs, based on several published studies[39,40,41]. The format of this document follows a questionnaire devised by ECN and commented upon by IT Power and Sunrise Technologies Consulting.

E.   NEPAL

E.1   Project characteristics

E.1.1   General project information

Nepal has a largely unelectrified population. Only 4% of the rural population have access to electricity[39]. The overall population has a slightly higher penetration of 14%. Nepal has one of the lowest per capita energy consumptions in the world of about 0.13 toe (1 512 kWh).

There are no deposits of fossil fuels so Nepal relies heavily upon traditional forms of fuel for cooking and heating, and imported fuel for electricity generation. There is a very large hydro resource in the country with a technically exploitable figure of over 20 000 MW – of which only 250 MW has so far been realised.

The country has a good solar regime with an average insolation of 4.5 kWh/m^2/day. Between 1995 and 1998 around 1 000 SHSs were installed with finance from the Government of Nepal via the Agricultural Development Bank of Nepal (ADB/N).

Three specific projects are detailed which are cited from a five month field study carried out in 1994/1995[40].

A. Bamti/Bhandar: a village in Nepal which had (at the time of the study) no SHSs but provided some useful background socio-economic information.
B. Pulimarang: this is the first village in Nepal to be installed with SHSs
C. Solu-Khumbu region: an area with a number of dispersed SHSs

There is additional data from a report published in 1999[41] which conducted extensive surveys on 250 SHS users – around 10% of the estimated total number of installed systems.

E.1.2   Objective(s) of the project

The Pulimarang project aimed to bring village wide SHSs to Nepal for the first time. For those families unable to purchase a system, a community centre was electrified and a television provided.

Installations in the Solu-Khumbu region were done on an individual basis. The region contains one of the main roads to Everest main camp and is inhabited by Sherpas. When asked about motivations for purchasing the systems 29%, of the 41 SHS users stated that they purchased the systems because of the "attraction and innovation" of the systems. Only 10% cited that they were actively searching for electric lighting. Only one of the 41 users mentioned that they purchased a system to save on kerosene consumption.

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[39] "Some Experiences with Practical Implementation of Photovoltaics Solar from Nepal", Shrestha G R, Solar Photovoltaic Power – The Power Supply of Tomorrow Conference, Copenhagen , 1998

[40] "What can solar electricity provide for Himalayan people? The case of Nepal" Schweizer P, Shrestha J N and Sharma D K, 13th European PV Solar Energy Conference, 1995

[41] Socio-Economic Study of Solar Home Systems Target Groups: Impact of SHS and SHS User Survey (AEPC/DANIDA) 1999

E.1.3 Description of the SHS(s) used in the project

Details are given for the Pulimarang project since it is the only one available that used a standard system:

System Size: 35 W_p.

Type of Panel: Siemens Pro Charger panel.

Quality of the Systems: One year after the installations 40% of the systems were not functioning correctly[40]. Problems mentioned by interviewee's included blackening of fluorescent tubes and low durability of the charge controller.

Type of Battery: 70 Ah lead-acid battery (no mention of deep-cycle).

Number and Type of Lights: Three 8 W lights.

Other Components: Distribution box and radio junction box.

Number of SHS installed: 46.

E.1.4 An overview of SHS project and market experience in the region to put SHS activities into context

1994 saw the first village SHS project. In 1997 Government subsidies of 50% were introduced. This lead to an explosion in the interest to install systems, so much so that the limited subsidy budget dried up. As of 1999 there was no new money from the Government.

Total installed SHSs as of 1998 amounted to 36 kW_p[39] compared to a total installed PV capacity of 1 093 kW_p. A large proportion of the installations (795 kW_p) is for telecommunications applications. Data from 1984[42] suggests 92 kWp of SHSs. It is not known whether the information is inaccurate or whether in the 15 years of time between the studies a large number have ceased operation. The former reason is more likely.

There were nine companies working in solar PV in Nepal in 1999.

E.2 Description and determination of GHG sources and system boundaries

This information is covered in later sections.

E.3 Current situation - description and, if possible a quantification

E.3.1 Energy use and expenditures of the households

Energy use of households

General situation: Electrical power in villages with no grid access comes solely from kerosene and candles for lighting and dry cell batteries for radios and cassette players. Battery lifetime is low and people discard used ones in a haphazard way[40], mostly unaware of the potential dangers to people and the environment. No mention is made of using battery recharging stations for charging car batteries. There are no formal plans to recycle batteries at the end of their working life although there are two battery recycling companies in Nepal.

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[42] Availability of Solar Energy in Nepal". Water and Energy Commission Secretariat. Singha Durbar, Kathmandu, Nepal, WECS 1984.

The energy use of households varies according to the region. An average national figure is given for households with and without SHSs. These figures are taken from the 1999 report[41].

Average of 125 households surveyed - No SHS

Utility	No. of hours/day	Energy source	Monthly consumption	Monthly energy costs
Lights	6	Kerosene, candles, etc	6.1 litres + 17.5 candles	Rs 307 (US$4.14)
		Dry batteries		
TV/radio	?		8.7 batteries	Rs 109 (US$1.47)

Average of 250 surveyed households - SHS installed

Utility	No. of hours/day	Energy source	Monthly consumption	Monthly energy costs
Lights	4.5	Kerosene, candles, etc	3.6 litres + 1.8 candles	Rs 178 (US$2.40)
		Dry batteries		
TV/radio	1		4.8 batteries	Rs 72 (US$0.97)

Television sets are only used in SHSs within the Central Development Region of Nepal. The reason for this is not known: it may be poor signal or lack of available power.

Alternative figures from the 1994/95 study[40] gave energy consumption figures for the village of Bamti/Bhandar. This is shown in the next table.

Bamti/Bhandar - No SHS installed

Utility	No. of hours/day	Energy source	Monthly consumption	Monthly energy costs
Lights	?	Kerosene, candles, etc	2-4 litres	US$0.6-1.2
		Dry batteries		
TV/radio	?		1-4 batteries	US$0.2-0.8

Kerosene is heavily subsidised in Nepal, which may have an affect on its use. The actual level of subsidy is not known, but the cost to consumers is US$0.3/litre.

Distance to Grid/Population Density
With a highly dispersed rural population the cost of grid connection is prohibitively high for a large proportion of the population.

The SHSs that are already installed are generally situated in the hilly areas of the country that are more sparsely populated than the low-lying southern plains.

E.4 Key factors, influencing the project impact and/or the baseline

E.4.1 A. Project specific factors

Adequacy of system design to users' preferences
It would seem from the 1999 survey that there is a sizeable residual use of kerosene and candles in households that have SHSs installed. It might therefore be assumed that the systems are not adequate or they are not performing adequately, or simply that they are providing additional lighting.

Quality of installations
When the Pulimarang project was visited one year after the installations took place 40% of the systems were malfunctioning. Surprisingly, 24% of the users with malfunctioning systems said that they were satisfied with their systems.

The survey of 250 systems in 1999 also suggested a quality problem with systems. 23% of the households questioned were not satisfied with their systems. Whether it is the quality of the installations that lead to the dissatisfaction is open to question, but references to problems with fusing, wiring and charge controller are mentioned. This is in addition to complaints about less light on cloudy days and other factors beyond the control of the manufacturer/installer.

Maintenance
According to the 1999 report 90% of the 250 users that were questioned were unaware that they had paid a guarantee (which would have ensured a manufacturers warranty). Around 75% of the users were experiencing operation and maintenance problems with their systems ranging from lack of spare parts, low durability of charge controller, lack of knowledge about the operation of the systems. Only 33% of the SHS users had received any after-sales-service.

Adjustments and replacements of spare parts
Repair and maintenance costs range between Rs 400 and Rs 750 per year in the Western Development Region. These costs need to be budgeted for when assessing affordability of the systems. Over the lifetime of the system the additional costs can be equal to the initial system cost.

Is theft an issue?
Not mentioned anywhere

Type of financing and delivery mechanisms used (cash sales, credit sales, fee-for-service)
The financing of systems has previously been done through government subsidy via the Agricultural Development Bank of Nepal (ABD/N). In 1998[39] the government was providing 50% subsidies up to a maximum amount of US$200. One third of the remaining US$200 cost was paid in cash by the households and two-thirds paid off in a three year loan at 16% interest. In Pulimarang, users were given the choice of a 50% subsidy with the balance payable immediately, or a 25% subsidy with the offer of a three year loan.

It is sometimes the case that users are able to borrow money from financial institutions, charging up to 28%[41] interest rates. These higher interest rates are often payable over shorter time periods.

Type and level/percentage of SHS subsidy (i.e., equipment "buy-down", interest rate subsidy, etc.)
 A government subsidy of between 25 and 50% has been available at various times in the 1990s. Funding was exhausted soon after the 50% subsidy was offered.

Satisfaction of the end-users about the system and income (factors that determine whether end-users are willing to pay for SHS services).
One of the conclusions from the 1999 report was that "on the basis of energy expenses [SHSs are] not affordable to the majority of the rural population". It is the case that although it is generally not cost-effective to purchase a SHSs the users are willing to pay for the good quality light from a non-polluting source. Regarding willingness to pay, from the 1999 survey[41] 14% of the users would have installed the systems without subsidy, 15% would have installed with Rs 5 000 (US$67) subsidy, but the majority (71%) would have only proceeded with subsidies of between Rs 10 000 (US$133) and Rs 12 000 (US$160).

E.5   External Factors

Kerosene Subsidies
Kerosene is highly subsidised at US$0.3/litre.

Income Development
Around 12% of households[41] stated that there was more time for income development activities.

Plans for Grid Extensions
The terrain in Nepal (75% land area are hills and mountains) is a major barrier to grid extension through the country. It is likely that the grid will extend only very slowly since there is already a power deficit and the terrain makes grid extensions particularly expensive. One solution to rural electrification that has made in-roads at the village-scale is micro hydro systems. It is important that SHSs are not installed where micro-hydro systems are planned.

It has been the case in Nepal that SHS have generally been installed in the hill districts. In all but one of the districts that were included in the survey there is "no possibility of installing micro-hydro or extending transmission grid in the near future"[41].

Legal aspects
The ADB/N is the Nepali government's channel for subsidies.

Socio-economic developments
In the village of Pulimarang[41] it was found that sleeping hours decreased for about 75% of adults, leisure activities increased in nearly 50% of households but only 12% of adults believed that income generation activities had increased. Time to teach children was acknowledged to increase in around 90% of the households.

Demographic developments
Unknown

E.6   Identification of baselines and selection of most likely baselines

No baseline calculations were made prior to these installations, therefore some retrospective ones have been made for this study.

How many baseline options have been considered?
The most obvious baseline to choose would be the use of kerosene and candles for lighting, prior to the installation of SHSs. The emissions from candles are comparatively small compared with those from kerosene lamps. See section 10.

Do you believe this was an appropriate baseline, and how could it be improved?
This is probably the most appropriate baseline. It may also be important to obtain data from the appropriate region within the country as regional variations of energy use can be substantial. For

example, in the Western Development Region amongst surveyed non-users of SHSs the average household monthly energy consumption consisted of 8.4 litres of kerosene and 15 candles, compared with in the Mid Western Development Region where an average of only 4.6 candles were used – no kerosene at all.

It might also be pertinent to include the use of dry cell batteries, but the embodied energy and associated emissions are not known for specific cases in Nepal.

An alternative to this baseline would be the extension of the grid but since this is such an unlikely option given the poor power availability and the hilly/mountainous terrain this would be less appropriate.

E.7 Estimation of energy services provided

Estimate of the energy services that will be delivered by the SHS and its development over the time
Field data[41] suggests that power from a system provides enough energy to supply an average of 4.5 hours per day of lighting and 1 hour per day for TV use (averaged over 250 SHSs). It is interesting to note that the 4.5 hours lighting is less than the average of 6 hours in households with no SHSs. This is thought[41] to be due to the fact that evening activities are conducted more efficiently in the good quality light.

E.8 Project Emissions

How has a Life Cycle Analysis been carried out - what were the assumptions?
A life cycle analysis has not been carried out. No allowance will be made for the CO_2 emissions from the PV system production.

Is kerosene lighting expected to continue once the SHSs are installed? If so, how much?
This is definitely the case. An average residual use of 3.6 litres of kerosene per month was recorded in the households with SHSs installed. This compares to an average monthly consumption of 6.1 litres of kerosene used in households with no SHSs. A factor in the high residual use could be the poor availability of the systems. As mentioned earlier, in the Pulimarang survey 40% of systems were not operating correctly.

In the 1995 survey in Pulimarang kerosene consumption was reduced by 82% but dry-cell battery consumption by only 15%.

E.9 Baseline Emissions

How was the calculation structured?
Average values of kerosene and candles consumption for all the non-SHS users (over all regions) was used to calculate 'before project' figures. This was compared with the values averaged over all the SHS users to give 'after project' figures. This is not an entirely satisfactory approach since there is the probability that households with SHSs are likely to be wealthier and may have had a higher initial kerosene consumption when compared with non-users. This possible source of error will have the effect of making the project emissions too conservative i.e. if the initial fossil-fuel based energy consumption had in reality been higher than the estimation using the non-SHS users data, the *reduction* in fossil fuel use would be higher than estimated and the CO_2 emissions greater.

This under-estimate of CO_2 savings will be 'moderated' by the fact that CO_2 emissions from the manufacture (and delivery) of the system have not been taken into account.

What values have been used?
Average 'before project' use of kerosene: 6.1 litres/month/household
Average 'before project' use of candles: 17.5 sticks

Average 'after project' use of kerosene: 3.6 litres/month/household
Average 'after project' use of candles: 1.8 sticks

Therefore, project savings of 2.5 litres of kerosene and 15.7 candles per household per month. This is a conservative estimate as mentioned in the above paragraph.

An alternative figure for kerosene savings is taken from a PhD Thesis by Petra Schweizer-Ries[43]. Surveys were carried out in two regions (Solu-Khumbu and Pulimarang) where average household savings of 4.66 litres of kerosene per month were recorded.

A value of 2.45 kg of CO_2 produced per litre of kerosene consumed will be used[44]. A value of 77.9g of CO_2 per 25g candle is used (based upon a carbon content of 85%[44] for petroleum derived candle wax).

E.10   Determination of crediting time

What lifetime and crediting time were applied?
A 20 year lifetime for the PV system has been used for this calculation.

E.11   Estimation of the emission reduction

Using the average kerosene savings of 2.5 litres per month, this would equate to 6.125 kg CO_2 per month per system. Over a 20-year lifetime this reduction in the use of kerosene would be 1 470 kg CO_2 per system. Using the higher figure of 4.66 litres of kerosene saved per month[43] leads to CO_2 reductions of 11.42 kg per month or over a 20-year lifetime, CO_2 reductions of 2 740 kg per system.

Regarding emissions from candles, an average candle mass of 25 g[45] is assumed (average burn rate 6.35g/hr and average life of 4hrs). In addition a carbon content of petroleum derived candle wax of 85% is assumed. For a saving of 15.7 candles per household per month this equates to 333g of carbon emissions saved. The amount of CO2 savings per household per month is then 1.22 kg. Over a 20 year lifetime the reduction in the use of candles would be 294 kg CO_2 for each system. This increases the saved emissions by 20% (over the conservative kerosene savings figure) and is significant.

For the reasons given in section 8, these values are subject to errors, which may or may not cancel each other out.

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[43] "Psychologische Faktoren bei der Nutzung regenerativer Energien: Eine Studie zum Einsatz von Solarteknik im Zentralen Himalaya", FhG-ISE, May 1996

[44] "Rural Electrification with Solar Energy as a Climate Protection Strategy", Renewable Energy Policy Project No. 9, Steve Kaufman

[45] "Rural Lighting: A Guide for Development Workers", Louineau J-P, Dicko M, Fraenkel P, Barlow R, Bokalders V, IT Publications 1994.

E.12 Evaluation of Additionality

Explain why the project would not be undertaken without being a CDM project given both the existing situation (costs, income distribution, technical status of equipment, regulation etc.) and the future situation (planned grid extension, income development etc.)

Following the drying up of government funds for 50% subsidies of SHSs there are a large number (2 000 as of 1999) of subsidy applications pending, awaiting announcement of a new round of Government subsidies.

It is only those households that are able to pay a premium for cleaner better quality lighting that are purchasing the systems i.e. poorer households cannot afford the systems even with a 50% subsidy. Therefore, without the government subsidy and any financial contribution from the CDM it is unlikely that projects which target poorer householders will go ahead.

Confirm that the project would not be undertaken with ODA sources as CDM projects should be additional to ODA

The PV market in Nepal has, as yet, made only small in-roads into the country. PV is not always recognised as a technology which addresses the needs of the poor and for that reason is not always seen as being suitable for ODA funding. However, it is evident from the surveys that have been conducted that it is the more wealthy members of the communities that can afford the systems. The CDM can help to bring SHSs and the clean, safe light that they bring to more sections of the community in an energy starved country like Nepal.

Conclude on the additionality of the project

SHSs emit less CO_2 than the majority of alternatives. Only in areas where micro-hydro systems are in use will SHSs not offset CO_2 emissions. In these situations a family with a local grid connection to a micro-hydro scheme would have no financial or other incentive to install a SHS. Therefore this possibility can be ignored.

How do you see this for future projects?

It would be important for future projects that the high residual use of kerosene is addressed. System quality and continued service must be priority areas if users are to gain maximum energy benefit from the systems. Unless this is the case they will continue to use kerosene, candles and batteries as a back-up.

Republic of South Africa

J.Cloin

Acknowledgement

SUMMARY

A case study of PV SHS in a project in South Africa is presented. A number of different baselines are presented, with an abatement potential of $40 - 230$ kg CO_2 per system per year. This would yield an emission reduction of up to 4.6 ton of CO_2 over its 20 year lifetime.

F.   REPUBLIC OF SOUTH AFRICA

F.1   Introduction

South Africa has a population of 43 million people with a GDP/capita of 2,990 USD. At the end of 1997, 81% of urban households had access to electricity, but as only 32% of rural households. The South African government is committed to rural electrification and sees it as an important contribution to its sustainable development objectives.

The South African Government's Energy White Paper states that: *"Government supports the concept of "Energisation", i.e. the widening of access to a safe and effective energy package within grasp of low-income households and will promote it's implementation where appropriate."*

At the launch of the Eskom-Shell Solar Home initiative, President Mandela outlined the benefits as follows. *"Electrification is central to improving the lives of those neglected by apartheid. That is why we give full support to efforts made by Shell and Eskom to bring our people electricity through the Solar Home System which is safe, affordable and friendly to the environment in which we live."*

The South African rural electrification project is executed jointly by Shell Solar and Eskom. The mission of Shell solar is 'to electrify the world's rural non electrified population using renewable energy.' The challenge for rural electrification is to make the technology affordable, as photovoltaics (PV) technology is expensive as compared to both conventional fuels (coal or diesel) and other renewable energy technologies such as wind energy and biomass, except for niche applications, such as is the case with widespread communities.

The project contributes to the 3 pillars of sustainable development:
- **Economic development** through the creation of 600 jobs and the payment of taxes and by increasing labour productivity.
- **Environmental protection** by delivering a carbon-free source of energy.
- **Social development** by delivering electricity to rural areas, enabling skills development and reducing rural to urban migration.

The CDM dimension of the project is to reduce the price at which the SHS is made available, by passing the value of the CER's on to the end-user. In this way, the price for the customer decreases and hence the customer base is increased.

F.2   Project Characteristics

The project aims to deliver the Shell Solar Home System (SHS) to 50,000 households in the Bipa region through a 'fee for service' payment scheme. This minimises up-front cost for the consumers and makes the technology therefore more accessible for the general population. The monthly fee for providing energy from a 50 Wp SHS is $7.60 , roughly the same they spend now on fossil fuels for lighting dry cell batteries and car battery charging.

The solar home system is made up of a solar panel, a charge controlled battery and a security and metering unit. Magnetic cards are used to store the pre-paid power credit that is drawn down as time proceeds. It is the first time that magnetic card based pre-payment has been used for a solar home system. The monthly charge is stored on a magnetic card that customers can buy from local outlets, which when inserted into the unit will power it for thirty days. A network of local outlets has been set up to market, train, install and maintain the solar home systems. By February 2000, 6.000 units had been installed. Depending on the success of this pilot phase (technology, financial set up and customer satisfaction) and the robustness of the business plan, the project will proceed with the objective to install another 44,000 SHSs from 2000 onwards.

F.3 Description and Determination of GHG sources and System boundaries

The system boundaries are the individual households. The GHG sources of the households are the burning of candles for lighting, the burning of paraffin for lighting and the charging of car batteries for TVs. It is assumed that dry cell batteries are not displaced through this project, providing for the case that no step-down converter (9 -> 12 V) is available, or no Ni-Cd chargers are present.

F.4 Current Rural energy situation

Before the introduction of the PV Solar Home Systems, households used paraffin and candles for lighting, batteries for flashlights and radio and car batteries for powering televisions.

Table 1: current energy use (Source: Benefits and Impacts of SHS – A case study of six households, EDRC, University of Cape Town)

Utility	Use [hours/day]	Energy Source	Annual consumption	Annual energy costs [US$]
Light		Paraffin		13.2
		Candles		41.1
Battery Charging		Car Battery	24.6 kWh	121

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

F.5.1 Project specific factors

The prepayment card enables the customer to a month of the PV SHS's energy, but failure to pay will probably lead to the original use of fossil fuels. Therefore, the CO_2 abatement potential of this project is largely dependent on the sale of the prepayment cards.

The theft of systems is expected to be minimal as the main components (module, battery and controller) are fitted with a 'smart switch'. This piece of electronics ensures that only specified combination of components can be operational. In case of tampering, the electronics have to be re-set by an official technician.

Tracking of particular systems is often a great burden in PV dissemination efforts. For establishing the exact impact of the systems, this project provides excellent opportunities since for each system there is a unique code and location, established by a Global Positioning System (GPS) device.

F.5.2 External factors

GDP Income is expected to grow at a rate of 0.6% but it is not known how this relates to the energy use in the baseline. In case of a grid extension, the user can easily contact the utility have the system be relocated. This has no lasting effect to CO_2 abatement.

F.6   Identification of baselines and selection of most likely baselines

Development in South Africa does not stand still. It is likely that increased demand for lighting and electricity will develop. It could be argued that some of the people that can afford a solar home system could have bought an alternative energy source, such as for example a diesel generator, had the SHS not been available. This could be local, diesel-generated power or power off the grid (which in South Africa is highly carbon intensive). One could also argue that these areas would by definition not get grid power (they are too far away from the grid) and that diesel-power generation is not an alternative as they are used for much higher power applications than SHSs can offer. The most likely alternative to SHSs would therefore be a growing use of the traditional lighting fuels.

F.7   Estimation of energy services provided

The incremental SHSs directly displace GHG emissions by substituting solar powered electric lights for the kerosene, other hydrocarbon lamp fuels, and candles commonly used in un-electrified homes. The households receive a daily charge of the battery of 10 Ah. This is equivalent to around 120Wh. On special occasions, they are able to 'overrule' the system and consume 10 Ah more. This system is designed to prevent the battery from depletion and should result in a relatively long battery life of 5 years.

Energy Supply		Energy Demand	
		Lights (4 * 11 W)	44
		Radio (6 hours play)	36
		TV (2 hours play)	60
Energy Available	150[46]Wh	Total	140 Wh

Table 2: Energy balance of a powerhouse (Source: own calculations)

F.8   Emissions of the project

The project emissions, i.e. Life Cycle Analysis emissions are neglected for this case.

F.9   Emissions of the baseline

There are a number of possibilities for calculating the baseline:
- "best guess" reference cases at the project level, taking the current use of energy as the baseline; as most of the SHSs will be installed in rural areas that were previously not connected to the grid, the SHS will replace traditional fuels, which could be taken as the base case. The offset of CO2 for one SHS is **230 kg** of CO2 per annum.
- "best guess" reference cases at the project level, taking the future use of energy as the baseline; this is a behavioural analysis looking at what potential users would have done if they would not invest on a SHS, which could be the increased use of kerosene for lighting with affluence grows.
- National / sector baselines using a technology matrix approach, with baselines defined specifically for SHSs. This could for example be based on average levels of kerosene consumption. It would minimise transaction cost relating to measurement, reporting, verification and assurance.
- Grid-based power supply[47]; at a macro-economic level, the carbon intensity is reduced. Possibly South Africa's energy-related CO_2 emissions could be divided this its total energy production, thus arriving at the average carbon intensity of electricity-supply, measured in CO2 per kWh. Assuming that the SHS produces 44 – 88 kWh of electricity per annum, which avoids power generation from coal, 1 MWh generated from coal releases 0.26 tonnes

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[46] Based on one 'overrule' per 4 days.

[47] Used in Ghana, as the government has a target of 100% electrification, see ; 'Solar Home Systems in Developing Countries and Climate Change Mitigation: A Global Assessment', April 1999 (draft), Steven L. Kaufman

of carbon, or 0.26 kg of carbon per kWh of electricity. Therefore, 44-88 kWh prevents the emission of 11-23 kg of carbon (or **40-80 kg** of CO_2). However, as SHSs are by definition implemented in rural area where there is no chance of electrification, grid-supplied electricity is not a valid reference scenario.

- "standard-to-beat" baselines; it could be argued that the standard to beat is the average current efficiency of supply in South Africa, as described above, or the efficiency of the latest carbon-based electricity-generating technology implemented in South Africa. However, as SHSs are by definition implemented in rural area where there is no chance of electrification, grid-supplied electricity is not a valid reference scenario. However, as noted above, SHSs will be installed in areas that will not be electrified.

F.10   Determination of crediting time

The crediting time in the proposed project is 20 years, equalling the assumed lifetime of the components.

F.11   Estimation of the emission reduction

Depending on the baseline chosen, the project will offset between 40 and 230 kg of CO2 per annum. During 20 years, this would yield .8 to 4.6 ton CO_2.

F.12   evaluation of the Additionality

Whether the project is commercially viable is still under investigation However, eligibility under CDM would have two effects.

0. it would improve the chance of the project gaining approval for phase two, i.e. selling the additional 44,000 SHSs
1. the rate and depth of market penetration of SHS in South Africa would be augmented (i.e., in addition to what would have occurred otherwise) if CDM credits are available to offset the cost of taking SHS to the next tranche of homes that are near-commercial but not fully commercial.

The value of the Certified Emission Reduction credits that could be earned by pushing SHS deeper into the market than would have occurred otherwise would be passed on to the consumers in question, thus making the installation of SHS financially viable in those instances. This assumes that the market is non-monopolistic, which is the case for photovoltaics. Therefore, a lower fee can be charged for the service provided, which would make the service more accessible for a broader population.

The project provides benefits of the incremental SHS are:

Real: if the incremental SHS would not be provided, the candles, kerosene and electric-operated batteries would continue to be used.

Measurable: the household will be expected to use the power provided by SHS, which is estimated to be 44KWh of electricity per annum per average household and double for more affluent rural communities. This can be measured by sampling of homes to confirm that fuel substitution has occurred as anticipated.
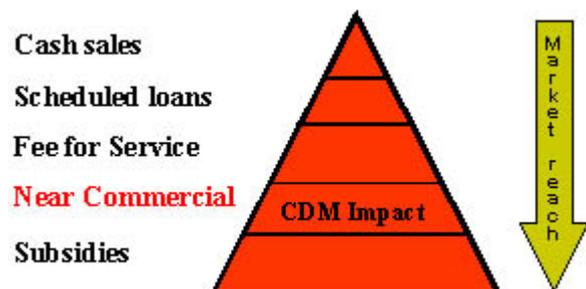
Long-term: they will reduce emissions over the lifetime of the project, i.e. as long as the SHS is in operation, although one could argue that eventually the user of a SHS would have been prepared to pay the higher price. This is known as the "free rider" issue. An option would be to have an expiry-date for the CER shorter than the operating lifetime of the SHS.

The investor in this case is the consumer, who in effect pays for the SHS through a 'fee for service'. However, it is impossible for each SHS user to apply for CER's. The role the JV would play in this instance is to project-manage the certification of the emission reductions, which involves interfacing with the South African government, operational entities, the CDM Executive Board, etc. In this case, the JV would pass on the value of the CER's to the end-user, after deducting certification cost, share of proceeds, etc.

In conclusion it can be said that the project is of limited significance with respect to carbon avoidance, especially if you would include the cost for measurement, reporting and verification of the emission reductions. However, the project is of high significance for sustainable development – improving the quality of life of rural communities in South Africa.

REFERENCES:

[1] Benefits and Impacts of SHS - A Case Study of Six Households, EDRC, July 1996
[2] http://vu.foundation.no/cdm_dialogue/project1.htm
[3] http://www.cia.gov/cia/publications/factbook/geos/sf.html

Swaziland

J.Cloin

Acknowledgement

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[48] PV Solar Home Systems have been installed in Swaziland, a country in Southern Africa with just over 1 million inhabitants[49]. 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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[48] Source: Review of the PV market in Swaziland, Evaluation of the Government PV Demonstration Project" (1999)

[49] 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[50] 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.

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[50] 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[51].

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.

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[51] 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[52] 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[53]	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[54] 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[55] per system		759.5
Overhead		
Project Travel emissions (3* EU-SD return)	6,051	
Total project emissions (400 systems)		**309,851**

Survey findings[56] 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.

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[52] 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.

[53] 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.

[54] LCA emissions according to Alsema (2000)

[55] Based on battery lifetime 3 year.

[56] 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[57] per month		**18.2**
Total emission of the baseline[58]		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


Net CO2 Savings PV SHS project in Swaziland
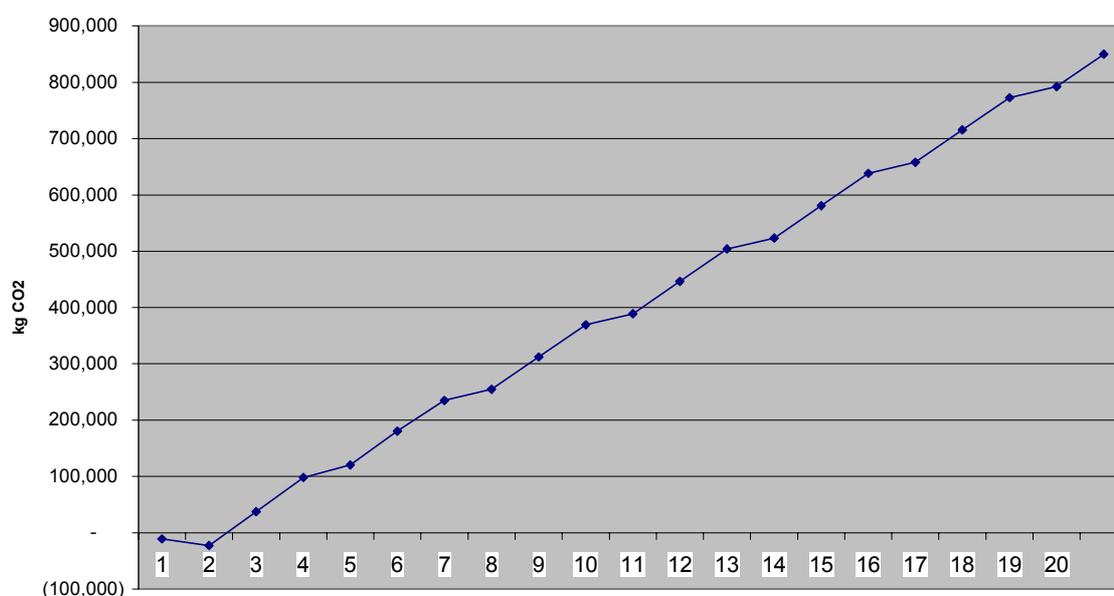
Figure 1: *emission reduction of 400 PV SHS in Swaziland as a function of time*

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

[58] 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.