NOVEMBER 2000 ECN-C--00-109

TOWARDS A STREAMLINED CDM PROCESS FOR SOLAR HOME SYSTEMS

Emission reductions from implemented systems and development of standardised baselines

J.R. Ybema
J. Cloin
F.D.J. Nieuwenhout
A.C. Hunt
S.L. Kaufman

ECN
Energy innovation

SUNRISE TECHNOLOGIES CONSULTING

it Power

Acknowledgement

This report has been prepared for the study 'Towards a streamlined CDM approach for solar home systems'. The study was financed by Novem, Netherlands Agency for Energy and Environment and the Shell Foundation. The authors wish to thank the members of the steering group, Li Hua, Jos van de Ven, Frank van der Vleuten, Stephan Rose, Murray Cameron and Erik Alsema for providing valuable comments. Robert Kleiburg and Jonathan Bates also provided useful contributions. The ECN project number was 7.7334.

Abstract

This report deals with the opportunities to streamline the CDM process for solar home systems. A streamlined CDM process would require standardised calculation of greenhouse gas emission reduction. The present report gives an overview of CO_2 emission reduction figures from 8 solar home system projects that have earlier been carried out. The best way to calculate the CO_2 emissions is explored. Two methods to standardise the assessment of emission reduction have been suggested and evaluated.

Contact:

Remko Ybema
ECN, unit Policy Studies
P.O. Box 1, 1755 ZG Petten, The Netherlands
ybema@ecn.nl

CONTENTS

EXECUTIVE SUMMARY

ECN, with the support of IT Power and Sunrise Technology Consulting, combining expertise groups on photovoltaics and quantification of emission reduction have been asked by the Dutch PV Export Group to study the eligibility of Solar Home Systems (SHS) under the clean development mechanism (CDM). The findings and recommendations are summarised below.

Solar home systems (SHSs) use solar energy to generate electricity for individual rural homes. They can be an excellent fit for the CDM objectives, but only if the value of Certified Emission Reductions (CERs) are not outweighed by CDM transactions costs. To streamline CDM baseline setting for SHS activities in order to keep transaction costs low, CDM eligibility rules should be fit for purpose and CER calculation procedures kept simple. To meet that goal, this study aims to determine the key factors underlying the emission reductions resulting from the implementation of SHSs and provides the key factors influencing these reductions.

To determine the key factors influencing carbon abatement, this study evaluates CDM-relevant details of eight solar home system projects and field studies in Africa, Asia, and Latin America. The case studies show that savings of kerosene for lighting provide the largest contribution to CO_2 displacement. In some cases, savings of candles and battery charging also contribute.

Based on information from the case studies and factors such as upstream emissions, the study concludes that over 70% of the SHSs have an annual emission reduction potential in excess of 200 kg CO_2. An abatement potential of 200 kg CO_2 per SHS per year can therefore serve as a conservative but safe global emission reduction value. While standardised baseline setting appears to be both possible and desirable, the case studies reveal a substantial variation in the carbon abatement from SHS installations both within and between individual countries.

Emission reductions depend on national characteristics (kerosene availability and subsidies, local norms), target groups (income level and related baseline energy use), SHS size and quality, and market characteristics (e.g., cash and credit methods for system financing). A customised approach to baseline setting can therefore be used as an alternative to global emission reduction values. However, the presented case studies do not yet provide enough information to specify numerically how the identified variables affect customised values. Therefore, in order to pave the way for PV SHSs in the current CDM negotiations, a global emission value would appear to be the most appropriate approach to use.

Depending on the outcome of forthcoming negotiations, the additionality of SHS activities might be determined based on (1) emissions additionality, (2) a positive list, (3) economic additionality, and/or (4) barrier removal. All the SHSs studied were found to demonstrate emissions additionality. Given their contribution to sustainable development and their greenhouse gas abatement attributes, SHSs have already been suggested for the 'positive list'. It will be difficult and costly to prove economic additionality of SHS activities on a case by case basis. The case studies learn that additionality is demonstrated through barrier removal. A financial contribution from CERs will reduce the cost to the end user and result in an increased SHS market size.

It is recommended that the 'CDM reference manual for emission reduction activities' should initially provide global emission reduction figures applicable to SHS activities regardless of individual project characteristics or location, and then gradually introduce customised elements when more detailed information becomes available. Further work is needed to fine-tune and build consensus for the global emission reduction figures. At the same time, analysts should develop a methodology to enable the generation of customised emission reduction figures on a 'per project' basis. It is further recommended that SHS activities be placed on a positive list or that their additionality be determined based on barrier removal. Under the barrier removal criterion, eligible projects should either (1) provide consumer credit, (2) provide training, business development, and/or company credit, or (3) support a certified cash sale. Only with these simple and transparent guidelines can solar home systems provide a substantial contribution to the objectives of the Clean Development Mechanism.

1. INTRODUCTION

1.1 Solar home systems under the Clean Development Mechanism

The Clean Development Mechanism (CDM) is an instrument established by the Kyoto Protocol for achieving sustainable development and contributing to the cost-effective mitigation of climate change. It allows Parties[1] to meet part of their reduction commitments abroad where specific greenhouse gas (GHG) abatement costs are lower. Simultaneously, this can allow developing countries to attract investments in clean energy technology and assist them in reaching a sustainable development path.

In order to be qualified under the CDM, Article 12 of the Kyoto Protocol specifies that emission reductions resulting from each project activity shall be certified, on the basis of:

a. Voluntary participation approved by each Party involved.
b. Real, measurable and long term benefits related to the mitigation of climate change; and
c. Reductions in emissions that are additional to any that would occur in the absence of the project activity.

Decisions on the principles, modalities, rules and guidelines of the CDM were expected to be taken at the sixth Conference of the Parties (CoP-6), which will be held from November 13-24 2000 in The Hague.

Emission reduction from CDM projects will be calculated against a baseline. This baseline represents the emissions that would occur in absence of the project. The Protocol demands for each CDM project a baseline study to be carried out that covers among others an additionality check (is the project additional to what otherwise would occur?), system boundary determination (what upstream emission effects are covered?) the emissions in absence of the project, the project's emissions and key factor determining these emissions. The Protocol also demand baseline studies to be verified by independent bodies.

A closer analysis of the CDM instrument reveals that it would be applicable to small-scale activities such as solar home system installations only if the baseline and monitoring methodology is sufficiently simple and generic to account for their dispersed characteristics and the relatively small amount of GHG reduction. Otherwise the transaction cost (due to baseline study, validation, registration, monitoring, verification and certification) would significantly reduce or even eliminate the additional revenues from the sale of Certified Emission Reductions. The CDM would then provide little or no incentive for such activities, causing an unwanted situation since many small-scale activities are advantageous from a sustainable development perspective.

This point has been recognised by various Parties in the climate negotiations; a recent version of the consolidated text on principles, modalities, rules and guidelines[2] suggests that: *'The executive board shall give priority to developing [standardised] [multi-project] baselines for projects below a specified size whose estimated emission reductions are less than AAA tonnes per year or BBB tonnes over their crediting period.'*

Some Parties have also suggested '…to adopt a[n initial] positive list of safe and environmentally sound eligible projects, based on the following categories:

(a) Renewable energy: solar energy, wind energy,…..'

---

[1] Being Parties to the United Nations Framework Convention on Climate Change.

[2] FCCC/SBSTA/2000/10/Add.2, Mechanisms pursuant to articles 6, 12 and 17 of the Kyoto Protocol, 26 October 2000.

The two preceding options could very much increase the prospects of the CDM becoming a supportive instrument for small renewable energy projects.

Streamlined approaches can reduce transactions costs. However, baseline approaches must address the tension between two fundamental objectives: maximising environmental integrity (by minimising unwarranted credits) and maximising investment in good CDM projects (by minimising transaction costs and crediting all additional projects).

Solar home systems are one example of a small-scale activity that can lead to GHG emission reductions. Solar home systems (SHS) are small photovoltaic (PV) systems used for stand-alone application in rural areas of developing countries. The systems consist of at least a PV module, a battery, wiring, and one or more electric lamps. They often also include a charge regulator, switches, and outlets for powering radio and TV. The electricity from the SHSs is used for lighting and to power small appliances such as radios and black and white televisions. As a result, SHSs reduce the consumption of kerosene, candles, and battery charging from fossil-fired power systems. From the point of view of the households, this will improve living standards by increasing the quality of light and decreasing the fire hazard and toxic fumes from traditional lighting. It will also relieve households from regularly charging a car battery by means of diesel generators or the grid in nearby villages.

Numerous other applications of PV systems exist, such as solar lanterns, PV-powered water pumps, and PV-powered telecommunication systems, centralised battery charging stations, etc. As far as such systems are additional to what otherwise would occur it is desired that standardised baseline approaches be also developed for these systems. However, as SHSs are expected to represent the bulk of the PV applications in developing countries in the near term, standardising baselines for SHS applications is a current priority.

Thus, there is a need for standardised SHS baselines that should be based on evidence from earlier SHS activities, both in terms of the estimated size of emission reduction and the key factors that determine the reduction size. With over 1 million SHSs installed worldwide[3], there is sufficient experience to draw some lessons on the size of emission reduction from SHSs.

The present study contributes to the development of standardised baselines for SHS by collecting evidence on emission reduction figures from earlier SHSs and generating ideas for the design of standardised baseline studies.

As part of as streamlined process it is not only essential to have a standardised baseline approach, the entire CDM process will need to be streamlined. This includes the host country approval process, but also validation, monitoring, verification and certification. It is noted that the latter elements have not been covered in detail in this study.

1.2 Objectives of the study

The specific objectives are:

1. To give an overview of the range of generic emission reduction figures for typical rural SHSs in relation to their energy services.
2. To identify what key factors are most important in determining emission reductions from these systems.
3. To generate ideas for the design of a streamlined CDM process for SHS projects (and document initial stakeholder feedback).

[3] Nieuwenhout, F. van et al, Monitoring and evaluation of solar home systems – experiences with applications of solar PV for households in developing countries, ECN report C--00-089, September 2000.

The key questions considered in this study are:
- What is the estimated emission reduction from earlier experiences with SHSs according to different case studies?
- How should emission reduction from SHSs best be quantified?
- What factors explain differences in emission reduction from the earlier experiences?
- What alternatives exist to standardise emission reduction calculations?
- What are the pros and cons of the different standardisation approaches?

1.3 Approach of the study

This section briefly describes the approach that was followed in the present study:
1. *Evidence from earlier case studies (see Chapter 2).* The first step in this study was to collect information from earlier SHS activities. The study team collected case study information following a consistent format and reporting template specifically designed to cover the CDM elements[4]. The case studies answered questions such as how was the project set up, who was involved, what were their roles, was it additional, why was it done, etc. The case studies also gave explicit information on how emission reductions from the projects were calculated, what factors were used in the calculation, and what the results were. The different ways to calculate emission reduction were compared.
2. *Further analysis of the case studies (see Chapter 3)*. The study team developed a comprehensive approach to calculate the emission reductions from SHSs. This was partly based on experiences from the case studies and partly on existing operational guidelines regarding how to set up a baseline study. The emission reduction figures from the case studies were then recalculated based on this comprehensive standardised approach and the differences in emission reduction figures were explained.
3. *Analysis of additionality of SHS activities (see Chapter 4)*. Different ways to address additionality for SHS activities are presented.
4. *Standardisation of the estimation of emission reduction (see Chapter 5).* Two alternative ways to standardise the estimation of SHSs' emission reductions have been developed. The pros and cons of these approaches are also given.

This study did not intend to develop a final answer to the question of how standardised quantification of emission reductions should best be done. Instead it aims to provide alternative ways to address standardisation that will further need to be discussed with a variety of stakeholders during and after CoP-6. A second phase for this study is foreseen for the first half of 2001 in which exchange of views will take place with different groups of stakeholders. This will include leading parties in developing countries, the World Bank and other international organisations, representatives from NGO's, industry, validators, and baseline experts.

CoP-6 may decide on the development of a CDM Reference Manual, that will give guidelines how to set up baseline studies for CDM activities. This study has provided groundwork that could be used in drafting the CDM Reference Manual, especially for the chapter on Solar Home Systems.

[4] The descriptions of case studies can be downloaded from http://www.ecn.nl/unit_bs/kyoto/mechanism/cdmshs.html.

2. EVIDENCE FROM SOLAR HOME SYSTEM CASE STUDIES

2.1 Selection of solar home system case studies

Introduction of SHSs has started in a number of projects during the 1980s, funded by governments and bilateral donors. Up to now, an estimated 1.3 million SHSs have been distributed in developing countries with a total capacity of around 40 MW_p. Projects continue to be the dominant SHS dissemination in most countries, yet commercial markets driven by commercial interests are also starting to emerge (Nieuwenhout et al, 2000).

Table 2.1 *Overview of SHS case studies that were analysed*

Country	Type of project	Number[1] of SHS installed in country	Number of systems planned in project
Argentina	GEF	2,000	65,500
Honduras	AIJ (US)	3,000	7,000
India	Commercial carbon offset funding agreement	118,000	182,000[2]
Indonesia	World Bank/GEF	80,000	200,000
Nepal	Government of Nepal	2,500	46
Kenya	Commercial cash sales	150,000	-
South Africa	Shell/ESKOM fee-for-service	60,000	50,000 (6,000[3])
Swaziland	IVAM/ ECN-Triodos Commercial credit scheme	1,200	400[3]

1 Total number of SHS installed in the country, not limited to the case study project. For South Africa, installed SHS are mainly small, and therefore less representative for the case study project.
2 Number of proposed systems in both India and Sri Lanka.
3 Approximate number of systems installed in the project.

This evaluation of case studies (see Table 2.1 for an overview) has been guided by a questionnaire that was developed for this purpose (see Annex A). Projects have been selected in different regions of the world. These projects were selected since they have explicitly quantified anticipated emission reductions and/or contain relevant survey information.

Information from the case studies has been supplemented by further analysis and interpretation and by information from additional projects carried out under the GEF and AIJ programmes. Some telephone interviews and email correspondences with SHS project operators have been conducted to gather further information and clarify project details.

Argentina

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.

Honduras
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 the SHS fee-for-service operation of Soluz Honduras. Currently in rural Honduras, households use kerosene, candles, and in some cases biomass for lighting, 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.

India
PV companies in Sri Lanka and India have recently benefited from a $500 000 grant for credit financing of 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. Trexler Associates, as part of their justification for the power plant, carried out baseline calculations for CO_2 mitigation for the project. The baseline calculations published in the 'Order' that came before the State of Oregon Energy Facility Siting Council use generic figures rather country-specific data.

Indonesia
The Indonesia project is a World Bank/GEF initiative 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 accelerated introduction of SHSs. A principal component of the project is a lending programme that will support a series of linked projects over time, where each will build on the lessons learned from the predecessor project.

Nepal
Nepal has a largely unelectrified population. Only 4% of the rural population have access to electricity[5]. Nepal has one of the lowest per capita energy consumption levels in the world of about 0.13 toe (1 512 kWh). About 2,500 SHS have been installed in the country to date. Survey results from three villages have been used in the case study.

Kenya
A well developed commercial market for SHSs exists in Kenya, with about 150,000 installed systems. It emerged in the mid-1980-s, with typical systems using 40 W_p modules. From 1989 onwards, 10-15 W_p amorphous silicon modules increased in popularity. The market is dominated by sales of commercial vendors. The Government facilitates this market with low duties and tax exemptions.

South Africa
With a population of 43 million people and a GDP of US$ 2990 per capita, South Africa is a relatively wealthy country in the context of Sub-Saharan Africa. However, only 32 % of the rural households are connected to the grid because of widespread settlement patterns. As a response, Shell Solar and Eskom are jointly executing a large rural electrification project. The project aims to deliver Shell SHSs to 50,000 households in the Bipa region through a 'fee for service' payment scheme. This minimises upfront cost for the consumers and makes the technology more widely accessible for the general population. 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.

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

Swaziland

About 1,200[6] PV SHSs have been installed in Swaziland, a country in Southern Africa with just over 1 million inhabitants[7]. Only 3% of all rural households are connected to the electricity grid, while about 1% obtain 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, the high cost of a grid connection, and the close proximity of most PV retailers. Between 1997 and 2000, some 400 systems were sold by Solar International Swaziland, mostly on a credit basis. Of these systems, there is broad knowledge on usage of the system, technical performance, and other energy use. About 100 households have been revisited recently during a survey on technical performance of system and user satisfaction.

2.2 Emission reduction according to selected solar home system case studies

Methodology of emission reduction calculation

The case studies provided substantial amounts of information on the factors determining emission reduction. All studies only reported reduction of CO_2 emissions; other greenhouse gases were not covered. The starting point for emission abatement calculation in each of the case studies is historic use of household fuels that can be substituted by electricity from a SHS. The required information usually comes from household energy surveys. In the cases of India and Indonesia, household surveys have been conducted before and after installations of SHSs. These provide the most reliable estimates of the actual fuel savings achieved. Surveys in Honduras, Nepal and Kenya have been conducted only after the SHSs have been installed. They rely on recall of previous fuel consumption quantities. Data presented in the Argentina case study are generic figures coming from other countries. In the case of South Africa household surveys have been conducted by EDRC, although not at the project location. Trexler Associates used an engineering approach for India where the three lights of the SHS are supposed to replace three kerosene lamps with total savings of 11.7 litres of kerosene per month. An additional annual CO_2 emission reduction is taken for battery charging.

The calculation of emission reductions in the eight case studies shows some differences in methodology and assumptions. Therefore not all results can be easily compared. In paragraph 3.3 the basic information of the case studies was analysed with a common approach to make outcomes comparable. Table 2.1 summarises the factors covered in the emission reduction calculations of the case studies.

Table 2.1 *Overview of factors covered in the case studies' calculation of emission reduction*

Factors covered in calculation of emission reduction	Argentina	Honduras	Indonesia	India	Nepal	Kenya	Swaziland	South Africa
Kerosene substitution	yes	yes	yes	yes	yes	yes	yes	yes
Candle substitution	no	no	no	no	yes	no	yes	no
Dry cell battery substitution	no	no	no	no	no	no	no	no
Battery charging substitution	no	yes	yes	yes	no	yes	yes	no
Correction for availability	yes	no	no	no	no	yes	yes	no
Programmatic effects	no	no	yes	no	no	no	no	no
Upstream energy use baseline	no	no	no	no	no	no	yes	no
Upstream energy use SHS	no	no	no	no	no	no	yes	no
Leakage effects	no	no	no	no	no	no	no	no

6 Source: Review of the PV market in Swaziland, Evaluation of the Government PV Demonstration Project' (1999).
7 July 2000 estimate, source: CIA Worldfactbook.

The main differences in the calculation of emission reduction:

- *Coverage of other kinds of fuel substitution than substitution of kerosene.* Most studies only considered emission reduction from the substitution of kerosene use. Some of the studies also considered replacement of candles and battery charging. Dry cell battery savings are mentioned in some cases, but not taken into account in the energy reduction calculations. The factors can have a significant contribution to total emission reduction.
- *Correction for availability of the systems.* The larger part of the studies has assumed an availability of the SHSs of 100% or almost 100%. Only in the cases of Kenya and Swaziland significantly corrected availability figures were applied.
- *Programmatic effects.* The Indonesian case study has included so-called programmatic effects. The rational is that the SHS project increases growth of the Indonesian SHS market. Therefore, (part of) the emission reduction from market development effects is claimed. The other case studies have not considered this effect.
- *Upstream emissions.* Except for Swaziland, in all of the case studies the household is the system boundary for calculating the emission reduction. Sometimes it was explicitly mentioned that upstream emissions due to production and transport of the SHS were expected to cancel against upstream emission in the fossil fuel chain. Usually, nothing was mentioned about life cycle emissions.
- *Leakage.* The studies did not consider leakage effects. Leakage is the increase in GHG emissions caused by the project activity outside the project boundaries. Leakage might be relevant in the case of SHSs if kerosene is sparse and, under the prevailing prices, demand for kerosene can not be satisfied. The kerosene not consumed by the household with a SHS might then (partly) occur elsewhere. Leakage is expected not to have a significant impact on emission reduction results for countries where availability of kerosene is not an issue.
- *Emission factors*. The case studies show small differences in CO_2 emission factors for electricity generation in case of battery charging. For kerosene lighting, the emission factors used are in the range of 2.4 (Argentina) to 2.55 (India) kg CO_2 per litre of kerosene.

Emission reduction figures

In Table 2.2 present the results from the case studies without adjustments. The table also presents the key figures that were used in the calculation of emission reduction. It appears that in most cases the size of the modules is in the same range (between 30 and 60 W_p). Only the Argentina case study covers larger systems, while in Kenya small systems (10 - 12 W_p) play a significant role.

Table 2.2 *Basic figures for calculating emission reduction in the case studies*

	Module [Wp]	Average kerosene [l/month]	Assumed crediting time [year]	System availability [%]	Annual CO_2 reduction per SHS [kg/year][3]
Argentina	50-400	15-21	15	96	504
Honduras	30-60	7.57	20	100	246
Indonesia	50	14.33	15	100	448 (758[1])
India	35 (20-53)	10	30	100	373
Nepal	35	4.66	20	100	79
Swaziland	50	4.4	20	80	125
Kenya	12-50	9	15	76	205
South Africa	50	8	20	100	230 (40[2])

1 Including indirect ‘programmatic effects’.
2 For direct comparison with the grid on a kWh basis.
3 Including savings of candles and battery charging.

The following observation can be made from Table 2.2:

- Emission reduction figures in the eight case studies show a large range, from approximately 80 to 500 kilograms CO_2 reduction per year, with an average of about 275 kilogram.

- The most important factor determining emission reductions, however, is initial use of fossil lighting fuels and battery charging. In all cases kerosene replacement accounts for the largest part of the emission reduction. Replacement of central battery charging, candles, and gen-sets also contribute to emission reductions.
- Various factors influence the extent to which potential energy substitution is realised. These are: availability factor of the PV SHS, kerosene subsidies, cultural factors, and adequacy of system design. The differences in initial energy can be explained by differences in income, subsidies and availability of fuels, and local norms and habits.
- The emission reduction from PV SHSs increase as system size [W_p] increases, but not in direct proportion.
- When a PV SHS receives proper maintenance, the availability factor is found to be higher. Early indications suggest that fee-for-service and credit systems encourage proper maintenance.
- Most studies have constant emission reduction figures over the lifetime of the project.
- Because no lifecycle emissions have been calculated, the crediting time does not affect the outcomes.

Ranges in emission reduction figures within a single case study
The basic survey results of some of the case studies were available. This allowed an analysis of the spread of results. It appears that emission reduction figures differ between households. In Honduras the range in emission reduction figures was between 0 and 3400 kg CO_2 per year. Low emission reduction figures were most commonly reported where pre-SHS kerosene use was low. In some cases, low emissions reductions were also reported where the system availability was low. [Note: out of the first 70 lowest reported displacement figures, system availability seems to have been a factor in 7 cases, while low pre-SHS kerosene use (i.e., 0.5 gallons or less) was a factor in 66 out of the 70 cases]. High emission reduction figures were caused by previous use of generator sets.

2.3 Additionality

To maintain the environmental integrity of the Kyoto Protocol, CER generating activities must be additional to what would otherwise occur. While the case studies of SHS activities participating in the AIJ and GEF programs have addressed additionality on an individualised basis, there may be ways to address additionality in broad terms without unduly restricting the potential of this sector or compromising the Protocol's environmental integrity.

From the case studies, it can be found that -additionality is typically demonstrated in the context of barrier removal.

The high up-front investment cost to a household in acquiring a SHS is has often been identified as the largest barrier to widespread market penetration. A financial contribution from CERs could help lower the initial system cost in the case of cash sales. In the case of credit sales and fee-for-service operations, CERs could help to lower periodic system costs. This argument has been used in the case study of South Africa, where cost reduction leads to a larger market share for fee-for-service customers that otherwise would not have had access to rural electrification.

In the Honduran case, CERs could likewise boost Soluz Honduras's fee-for-service operations through some combination of lowering costs to system users or increasing profitability, which would attract additional capital for project expansion. While the project has not yet benefited from 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.

In the Swaziland case study it is argued that, between 1996 and 1999, the project's credit component increased the PV market with a factor 3. This is an indicator of additionality, since it shows that without the effort, the market would have remained smaller. More so, since after the closing of the credit facility, SHS sales and average system sizes dropped back to significantly lower levels. This is also the case in the description of the Indonesian project; calculations are provided on market size at incremental cost levels. In Nepal, the case study describes the situation where SHS sales virtually stopped after the government-subsidised credit scheme ceased. This is an additional indication that the upfront system price is an important market barrier.

2.4 Findings

Summarised, the analysis of the case study resulted in the following findings:

1. While the case studies provide substantial amounts of information on the factors determining emission reduction, they are not always complete.
2. All case studies estimated emission reductions from substituted energy use.
3. The average size of SHSs differs in the case studies.
4. Calculation methodologies differ.
5. The range of emission reduction figures according to the original case study reports is large. The average emission reduction in Nepal amounts to 79 kg CO_2 per year while the average emission reduction in Argentina was calculated to amount to 504 kg CO_2 per year.
6. The most important factor determining emission reduction is initial energy use that can be substituted for by SHSs.
7. In all cases kerosene replacement accounts for the larger part of emission reduction.
8. Replacement of central battery charging, candles, and generators also contribute to emission reductions.
9. Various factors influence the extent to which potential energy substitution is realised. These include: system availability factor, kerosene subsidies, cultural factors, and adequacy of system design.
10. Differences in initial energy use are caused by differences in income, subsidies and availability of fuels, and local norms.
11. Emission reduction from PV SHSs increase as system size increases, but not in direct proportion.
12. With proper maintenance, the availability factor is higher.
13. Additionality is typically demonstrated in relation to barrier removal.

3. FURTHER ANALYSIS AND LESSONS FROM COMPREHENSIVE ESTIMATION

3.1 Introduction

The analysis in Chapter 2 has made clear that emission reduction calculations and the estimated values differ somewhat from case to case. To provide a better basis for standardising emission reduction figures, a consistent methodology must be applied to provide more comparable numbers. Section 3.2 of this chapter presents a standardised yet comprehensive approach to calculate emission reduction from SHSs. This approach takes into account all factors that are considered important, including lifecycle emissions from the PV module and the battery and realistic estimates of the availability of SHSs over their lifetime. In Section 3.3, adjusted emission reduction figures are given for the various case studies based on this standardised comprehensive approach. This latter section also gives:

1. an analysis of the differences between the case studies,
2. an analysis of the relevance of life cycle emissions,
3. an analysis of the impact of systems size on emission reduction.

3.2 Additional factors to consider

SHSs are being applied in households, which differ with respect to their size, income, habits, and preferences. As a result, the energy consumption of households also differs. When a SHS is introduced in a household the effects on energy consumption will likewise differ. In addition, the emission reduction is influenced by the way the system is used and maintained. With the help of surveys it is possible to gain a fuller understanding of the actual emission reductions that result from SHS installations.

The most common energy services for which the electricity generated in SHSs is used are lighting, television, and radio. For an analysis of GHG emissions, it is convenient to categorise energy services demand in three categories, related to the type of energy carrier used:

1. Fuels used for lighting (mainly kerosene and candles).
2. Car batteries used for television and other appliances.
3. Dry cell batteries used for smaller electric appliances.

The suggested basis for calculating emission reductions from SHSs is to compare quantities of energy carriers before and after the implementation of SHSs. This method will lead to measurable emission reduction figures if the fuel use figures before and after the SHS is implemented are known. Alternatively, substitution might be based on a comparison between the energy service provided by the SHS and of the traditional sources (to the extent that they are directly comparable). This is certainly not the case when an electric light substitutes a kerosene lamp. The quality of the electric light is much higher, and also the light intensity levels are usually higher. Correcting for the higher energy service would easily lead to endless discussions on how to value the differences in quality and intensity. Alternatively, one could consider grid electrification as an alternative baseline.[8] In most cases, however, continued use of the pre-SHS energy sources would be the most likely scenario. Thus the former method is preferred.

[8] The possibility of a grid electrification baseline is considered in Kaufman, S., Duke, R., Hansen, R. Rogers, J., Schwartz, R., and Trexler, M. Rural Electrification with Solar Energy as a Climate Protection Strategy, Renewable Energy Policy Project, Washington, D.C., January 2000. See www.repp.org.

For a comprehensive analysis, system boundaries are suggested in such a manner that they cover upstream effects and life cycle effects from the SHS.

Approach
The following steps have been made to determine the CO_2 reduction figures:

1. Calculate fossil fuel savings due to introduction of the SHS. This is the most crucial part, which is sometimes hampered by lack of suitable data. Depending on data availability there are five options in descending order of preference:
   a. Fuel savings have been determined in surveys[9] before and after installation of *SHS (India-Sundarbans, Indonesia*).
   b. Recall of previous fuel use of current SHS users *(Kenya, Honduras, Nepal).*
   c. Use general household survey data and correct for differences in income *(Swaziland).*
   d. Engineering approach comparing number of hours of lighting with different lamp types *(India - Trexler Associates).*
   e. Use fossil fuel savings figures from other countries if case studies do not provide all figures (e.g. for substitution of candles) *(Argentina, South Africa*).
2. Make a correction for the expected unavailability of the SHS over the crediting time. Default values for availability have been applied. Higher availability factors have been assumed for SHS projects that include a maintenance element: fee for service systems (85%) or credit systems (80%), and lower in case of cash sold systems (65%). Where actual availability figures are available, these have been used *(Swaziland, Kenya).*
3. Multiply fossil fuel savings with their specific CO_2 content. For savings of battery charging trips, CO_2 emissions of electricity generation as well as transport have been accounted for. The CO_2 emission factor assumed for electricity generation is an average for grid and diesel generator sets: 1.025 kg/kWh.
4. Add upstream life cycle emissions of the fossil fuels. In the case of kerosene a constant factor of 15% has been used to reflect refining and transport losses.
5. Subtract the life cycle emissions for producing and transporting the SHS.
6. Calculate the net emission reduction in kg CO_2 per year per SHS by dividing life cycle emissions by the crediting time.
7. Leakage effects have not been considered, as too little information is available. Leakage is the increase in GHG emissions caused by the project activity outside the project boundaries.

3.3 Emission reduction in the case studies based on revised analysis

An approach is presented here to determine CO_2 emission reduction for SHSs according to the seven steps detailed in the previous section. It is illustrated with the data of the case studies, which have been modified and added to our own assumptions and methodology. Differences with the results of the case presented in Section 2.2 are due to the use of additional survey information with data on substitution (Honduras and India), the addition of lifecycle emissions, and applying assumptions about system availability that are more consistent with reported field experience.

Emission reduction in the case studies
With the help of the LCA analysis of the SHS and the battery-charging alternative we can correct the direct CO_2 savings in the households to obtain the net savings. In Table 3.1 the results are presented using data from the case studies, extended with further survey results and assuming certain levels of availability. Average annual emission reduction figures have been calculated for two different time horizons. 12 years has been chosen as the period between 2000/2001 and 2012, and 20 years is a common estimate of the lifetime of a solar home system.

9 Kerosene displacement can vary from different SHS projects, even within the same country. The Selco systems in India are not subsidised and come with 3 or 4 lights, whereas the Sundarbans ones got 50 % subsidies upfront and came with just two lights. So kerosene displacement could be somewhat different.

Table 3.1 *Best estimates for emission reduction of 50 W_p SHS with 12 and 20 year crediting time*

	Kerosene savings [l/month]	System availability [%]	CO_2 reduction with 12 year crediting [kg CO_2/SHS/yr]	CO_2 reduction with 20 year crediting [kg CO_2/SHS/yr]
Argentina	15	85	390	394
Honduras	6	85	171	176
Indonesia	14.3	80	346	351
India	6.3	85	159	164
Nepal	4.66	65	74	79
Swaziland	4.4	80	120	125
Kenya	13.6	76	339	344
South Africa	8.2	85	227	232

Table 3.1 shows that the impact of the choice of crediting time on annualised carbon abatement is very small. This is caused by the fact that the life cycle emission of a SHS is dominated to a large extent (80-90%) by the contribution of the batteries, which do not depend on the crediting time. Of course, the crediting time will have a large impact on the calculated carbon abatement over the lifetime of a SHS.

Compared with the case studies, our standardised analysis shows a comparatively large range, between 80 and 400 kg CO_2 per system per year, but at a lower average level of about 230 kg/year. It should be noted that the calculations in Table 3.1 for the two cases with the largest kerosene savings (Argentina and Indonesia) do not account for emissions reductions from displaced battery charging and candle use. Furthermore, the figures also apply an assumed system availability factor that reduces estimated emissions in a way that might already (at least partly) be accounted for in the reported figures for kerosene displacement. So the figures in Table 3.1 may tend to understate actual emissions displacement.

LCA emissions of producing and transporting SHS

Life cycle emissions for two standard SHS sizes have been calculated. The ‘large’ 50 W_p system consists of a multi-crystalline PV module, a 100 Ah flooded lead-acid car battery, a battery charge regulator and plastic battery case. The ‘small’ system consists of a 12 W_p amorphous silicon module, a 70 Ah battery and a battery charge regulator. Two cases have been taken, one where 90% recycling of the batteries has been assumed, and another with no recycling at all. CO_2 emissions over the lifetime of the system are presented in Table 3.2.

Table 3.2 *Life cycle emissions of SHS in kg CO_2 over a system life of 20 year: assumptions and results*[10]

	'large': 50 W_p mc-Si, 100 Ah [kg]	'small': 12 W_p a-Si, 70 Ah [kg]
Module	98.5	17.2
Battery (1 unit) 90% recycling	58.9	41.2
Battery (1 unit) no recycling	103.6	72.5
Cables	7.5	2.9
BCR and casing (2 units)	20.7	0.9
International transport	5.9	5.8
Local transport	12.5	2.5
Total excluding battery	143.5	26.7
Total with battery life 2 yr, 90% recycling	732.5	438.7
Total with battery life 2 yr, no recycling	1179.5	751.7

LCA analysis of battery charging before the use of SHS
In some countries there is substantial use of car batteries before people obtain a SHS. These batteries are charged either in nearby places with a grid or with a diesel generator set. To calculate the CO_2 emissions per charge we made a number of assumptions that are presented in Table 3.3.

Table 3.3 *Life cycle CO_2 emissions for battery charging*

		Electricity source		
		Diesel genset	Grid	Average
Battery charging efficiency	[%]	85	85	85
Efficiency of AC/DC inverter	[%]	80	80	80
Specific CO_2 emissions	[kg/kWh][11]	1.25	0.8	1.025
Transport emissions per charge	[kg CO_2/charge][12]	0.28	0.28	0.28
Battery lifetime	[years]	1.5	1.5	1.5
Number of charges per month	[2/mo]	1.5	1.5	1.5
Annual CO_2 emissions (70Ah)	[kg/yr]	60	55	57.5
Annual CO_2 emissions (100Ah)	[kg/yr]	84	76	80

Note that the calculated annual CO_2 emissions strongly depend on the lifetime of the battery.

From Table 3.3 one can conclude that annual CO_2 emission differences between the two charging options are relatively small. Except for the case of Swaziland, where all battery charging takes place via the grid, we have little information about the source of electricity in the other countries. However, when assuming 50% diesel and 50% grid, the resulting error will always be lower than 5%

Small SHSs
Only in case of Kenya, information was available about kerosene savings due to the application of small SHS. Survey results show an increase in kerosene saving with increasing system sizes. In Figure 3.1, this relationship appears fairly linear, but the increase in kerosene savings is not proportionally to module size. Kerosene savings of a 12 W_p are 6.3 litres per month, for example, amounts to 43% of the savings of a 50 W_p system. The same source mentions savings in the

[10] Source (except local transport): E.A. Alsema, Environmental life cycle assessment of solar home systems, Report NWS-E-2000-15 (Draft) September 2000.
[11] Emission factors for diesel and grid are based on Alsema, see previous cit. The grid electricity supply figure is based on 55% coal fired power plants.
[12] For transporting the batteries to a charging station the following assumptions have been made: total travelling distance 30 km; fuel consumption 8km/l; 3% of the vehicle emissions are attributed to the battery. This results in 0.28 kg of CO_2 per charge.

number of trips to charge a battery of 1 to 1.5 trips per month, independent of the size of the SHS.

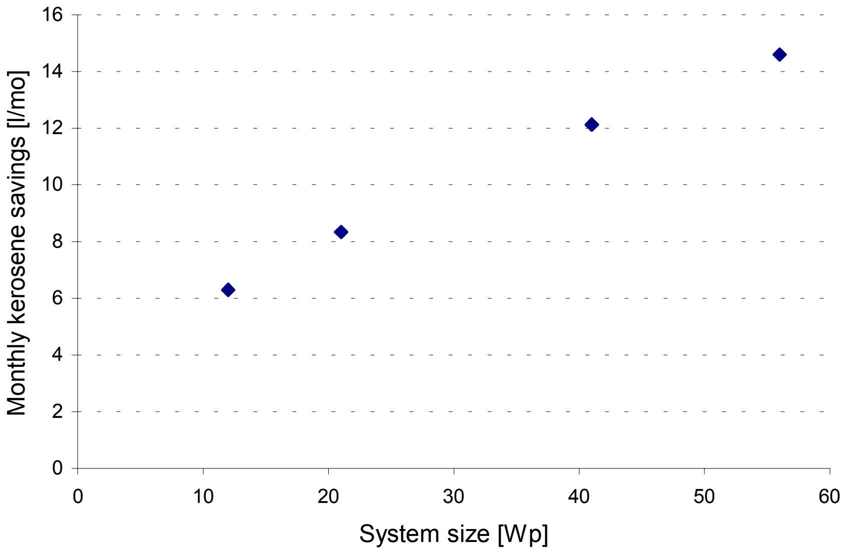

Figure 3.1 *Kerosene savings for different SHS sizes in Kenya*
Source: R. van de Plas and Mark Hankins, Solar Electricity in Africa: a reality, Energy Policy, Vol. 26, No. 4, pp. 295-305, 1998

Savings of 1.5 battery charging trips per month results in CO_2 savings of 10.5 kg per year. Adding that to the kerosene savings in Figure 3.1 results in the CO_2 abatement graph shown as Figure 3.2.

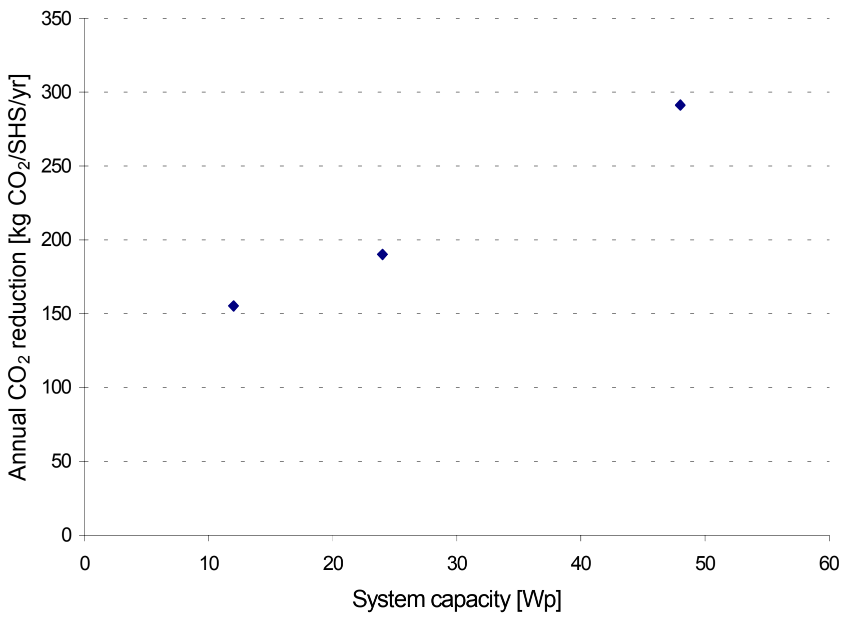

Figure 3.2 *CO_2 reduction of SHS in Kenya using different number of amorphous silicon modules*

One 12 W_p system results in CO_2 reduction of 155 kg per year. This is approximately half of the savings due to a four times larger system of 4 × 12 W_p modules (291 kg/yr) or a single 50 W_p module (344 kg/yr).

4. ADDITIONALITY TESTING

As mentioned earlier maintaining the environmental integrity of the Kyoto Protocol will require that CDM credits are given only for activities that would otherwise not be expected to occur. Commercial distribution channels have often proved to be the most successful and durable approach for disseminating SHSs to end-user, through methods ranging cash sales in open markets to private energy service company operations. In that context, additionality will be affected by the rate of market development and the willingness of private parties to invest in distribution channels, factors will be difficult and expensive to assess accurately and consistently on an case-by-case basis. In the case of SHS activities, there may be ways to address additionality in broad terms without unduly restricting the potential of this sector or compromising the Protocol's environmental integrity.

4.1 Relevant background on SHS

With an estimated 300 to 400 million off-grid developing-country homes, and a current installed base of only about 1 million developing-country SHS installations worldwide, SHSs have not yet made significant inroads into the rural energy baseline. Many countries have practically no experience with SHSs; even where SHS activities are most advanced, (e.g., Dominican Republic and Kenya), penetration is still only about 4%.

Several studies have identified specific market barriers to SHS dissemination. For example, according to a recent project document for the Solar Development Group:

'There are a number of specific barriers which are limiting the development of the rural, off-grid SHS market. They include: (i) lack of medium-term financing available to enable consumers to repay the high initial cost of PV systems over time; (ii) lack of availability / supply of PV products and systems to rural customers, which is due to weak capitalisation of local PV companies, risk averse financial institutions, and weak rural payment collection networks; (iii) unrealistic expectations regarding the future availability of the grid or the relative cost of PV power; (iv) very limited consumer awareness of the benefits of SHS among non-users, and a lack of managerial and technical skills among many companies selling and installing PV systems; (v) policy barriers such as market distortions in electricity tariffs, subsidies for conventional fuels, and high import taxes and duties on PV modules, materials, and auxiliary components which remain widespread and create an uneven playing field for PV and other renewable energy technologies.'

Due to the numerous and substantial market barriers, SHS installations are not yet 'business-as-usual' anywhere, even in those countries where efforts to remove the barriers are already underway.

4.2 Approaches to Additionality Testing for SHS projects and market activities

The appropriate approach to additionality testing for SHS activities will most likely depend on how the CoP determines additionality tests should be conducted generally.

1. If CoP decides that all 'emissions additional' projects (whose activities can demonstrate that they result in GHG reductions) are considered additional, then all SHS installations should be considered additional.

2. If CoP selects a 'positive list' approach, designating all activities in selected categories as additional, then -- given their positive attributes with regard to environment and development as well as low prevailing market penetration rates -- SHS installations have already been suggested to be on the positive list.

3. If CoP decides that all projects must demonstrate, through an individualised analysis, that they would not occur without the generation and sale of CERs, then SHS activities will likewise need to make such a demonstration. If exceptions are allowed, enabling projects to be categorised and screened based on indicators of their additionality, then it is suggested that additionality be tested in the context of 'barrier removal' as described immediately below.

4. If CoP decides to accept projects that demonstrate that their inclusion in the CDM will help to overcome implementation barriers, then it is suggested that all SHS project activities after the official start-date for CER generation (i.e., the year 2000 or whenever) should be considered additional if they use new resources to:

a. Provide consumer credit for system purchases, helping to overcome the first-cost barrier (in this case, CERs would be generated by all of the financed systems)
b. Provide SHSs on a fee-for-service basis, helping to overcome the first-cost barrier and ensure long-term maintenance (in this case, all fee-for-service systems would generate CERs).
c. Provide training and/or business development services for SHS businesses, helping to overcome the barrier of system availability (in this case, CERs would be generated by all installations from assisted businesses, including cash sales) [this may be hard to track, and could require safeguards to avoid double-counting]
d. Help to expand cash sales of systems meeting some type of certification or quality criteria, even in existing markets, until a predetermined level of penetration is achieved. In this case, CERs would be generated by all qualifying SHS installations until the predetermined level of market penetration is achieved. The level of market penetration could either be specified for individual countries or globally. This would recognise the nascent character of the SHS market, where all additional installations of well-functioning systems would help to prove the viability of the technology and demonstrate its benefits, thus helping to build markets. Cash sales of well-functioning systems would help to overcome the lack of knowledge regarding the benefits of SHSs. The predetermined limit would be set at the point where the SHS market would be considered mature, again either within a given country or globally.

The approach outlined above would trade relative simplicity for probably at least some free-rider installations that would happen without CDM participation. The environmental consequences would be fairly insignificant, and might be more than offset by the market catalytic nature of a CDM framework that encourages and helps to accelerate SHS dissemination. In reality, even this 'simple' framework would require substantial further work and require adaptations in practice.

4.3 Exclusion of projects receiving GEF and ODA support

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 projects such as the Solar Development Group and PVMTI that target multiple countries. Furthermore, several countries have provided bilateral support for SHS initiatives and other rural renewable energy activities.

A simple 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.

5. STANDARDISING THE ESTIMATION OF EMISSION REDUCTION FROM SHS ACTIVITIES

5.1 Level of aggregation for standardisation of baselines

If a standardised approach is used to elaborate an emissions baseline, there are many different ways it could be drawn up. The grouping of various types of potential projects into a single category with a corresponding single baseline is the defining aspect of standardised baselines. Not surprisingly, then, the definition of these categories is one of the principal challenges[13].

Different types/levels of aggregation are likely to be appropriate for different types of projects if the baselines developed are to be credible. Recommendations for appropriate aggregations have not yet been developed.

For SHS two different levels of aggregation have been considered:
- Global emission reduction values (one figure for emission reduction per typical SHS).
- Customised emission reduction values.

These are described in the following sections. In Section 4.4 the two aggregation levels are compared.

It is noted that, for all kinds of standardised emission reduction values, regular updates will be required to maintain reasonable accuracy over time. This could be based on random surveys of CDM-SHS projects.

5.2 Global emission reduction values

The approach with the lowest transaction costs consists of a single number that can be applied for all SHS irrespective of the country. Given the substantial difference between large and small systems (see Figure 3.1), at least a distinction between ‘small’ (6-25 Wp, typically 12 Wp) and ‘large’ (25-100 Wp, typically 50 Wp) system size needs to be made[14]. In Table 5.1 the results are summarised for the standard sized system of 50 Wp.

---

[13] M. Lazarus et al., Key issues in benchmark baselines for the CDM: aggregation, stringency, cohorts, and updating, Stockholm Environment Institute, Boston, June 2000.

[14] In Kenya, the distribution of SHS sizes shows roughly two broad peaks, one between 6 and 24 W_p and another between 30 and 80 W_p (see Figure 1, in Robert J. van der Plas et al, see citation of Figure 3.1). This would support a choice of around 25 W_p as boundary between the two sizes. Further research in other countries is required to strengthen this relation between SHS size and carbon abatement.

Table 5.1 *Quantity of installed SHS per country and CO_2 emissions according to the standardised approach*

	CO_2 emission reduction per 50 W_p SHS [kg CO_2/system/yr]	Total number of SHS in country [thousands]	Cumulative total number of SHS [thousands]
Nepal	79	2.5	2.5
Swaziland	125	0.8	3.3
India	164	118	121
Honduras	176	3	124
RSA	232	60	184
Kenya	344	150	334
Indonesia	351	80	414
Argentina	394	2	416

By listing the countries in their order of increasing CO_2 emission reduction per system and plotting this in a graph with the cumulative total number of SHS installed in the different countries, one arrives at Figure 5.1.

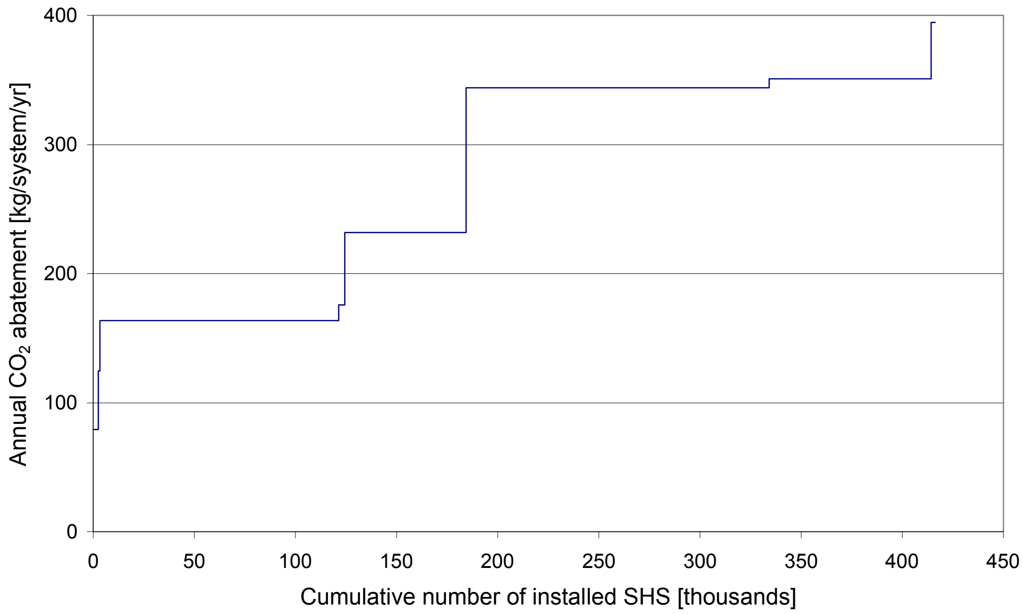

Figure 5.1 *Best estimates for CO_2 emission reduction presented as a function of the cumulative number of installed SHS in eight countries*

There are a number of options to construct a single global emission reduction value from the data of the eight countries. A close look at the table shows that 70% of the cumulative number of SHS in the different countries have a CO_2 emission reduction per SHS that is 232 kg per year or higher. This is also the case for any value in the range of 176 to 232 kg per year. To take into account the uncertainty in the exact level of the calculated CO_2 emission reduction, the largest confidence can be achieved when choosing the middle value of 204 kg CO_2 per year. One can conclude that 70% of the installed systems have an emission reduction of 204 kg CO_2 or more. Again, this is a conservative estimate since it includes a system availability factor that might already be reflected in reported kerosene displacement figures.

An alternative way to calculate a global emission reduction value would be to use the simple average of the eight cases. This results in 233 kg CO_2 per system per year. A third alternative would be to use a weighted average in which countries with a large number of installed systems weigh more heavily than countries with a smaller number. Using the national number of installed systems as weights, one arrives at a weighted average of 275 kg CO_2 per system per year.

The differences in the three possible estimates of the global emission reduction value reflect the remaining uncertainties in determining this figure. This would support the choice of a rounded figure. A value of 200 kg CO_2 per system per year would then be an appropriate choice that is on the conservative side.

As shown in the previous chapter, the CO_2 savings due to a system with 12 W_p is approximately half the amount of a 50 W_p system. It is therefore proposed to use a global emission reduction value of 100 kg CO_2 per SHS per year for 12 W_p systems.

Monitoring requirements
Monitoring issues have not been studied in this study and more analysis for this element is required. The monitoring requirements for SHSs are considered small, if global emission reduction values are used. The only thing that has to be shown is the number of SHSs that have been distributed or implemented in a certain period. Existing SHS distribution channels may be used for such monitoring activities, where retailers report the serial numbers of SHSs sold. But monitoring whether the systems are still in operation is certainly an issue.

5.3 Customised emission reduction values

Survey data are the basis for estimating customised emission reductions.

The case studies have made clear that emission reduction values of SHSs differ. The key factors that determine emission reduction from SHSs are:

- *Average use of kerosene prior to the installation of the SHS.* This is largely determined by:
    1. Income of households in rural areas.
    2. Availability of kerosene.
    3. Kerosene subsidies.
- *Size of the PV module.* Larger systems tend to lead to larger emission reductions than smaller systems, although not proportionally.
- *Availability of the SHS.* Systems that are better designed, operated, and maintained tend to have higher availability.
- *Habits.* Lifestyle differs from country to country.

It is noted that other factors also play a role, but their effect on emission reduction appears to be smaller.

Thus the emission reduction depends on *national* characteristics (kerosene availability and subsidies, habits), *system* characteristics (size and quality of the SHS) and *market* characteristics (fee-for-service and credit systems). Customising could thus be done making a distinction between countries, and/or system sizes and/or market characteristics.

Setting up a customised emission reduction value that account for national differences could be done for example by clustering countries and adopting emission reduction values of similar countries.

A possible system with customised reduction values accounting for system characteristics could start with default values per region and system size. The default value would be a value that is generally applicable to the institutional settings that give the most uncertain emission reduction (for example, cash sales in an unregulated market) and allows optimisation in case of strictly managed projects or activities benefiting from quality assurance procedures. Then, the methodology could suggest the possibility to claim a higher than default emission reduction figure on a project basis if the project provides sufficient evidence that a higher than default value is applicable, e.g. if a maintenance plan is provided that meets a certain standard.

The presented case studies do not yet provide enough information to give customised values as was done for the global emission reduction value for the standard system size. Additional survey information needs to be collected from new survey activities to develop such customised values. Based on the information collected for the present study it should be possible to indicate what kind of information should best be collected to maximise.

5.4 Comparison

An initial comparison has been made between Global and Customised emission reduction values. Five criteria have been considered for the comparison. Table 5.2 summarised how the two systems rank with respect to these criteria.

Table 5.2 *Comparison between Global and Customised emission reduction figures for SHSs*

Criteria	Global	Customised
Transaction costs	+	-
Credibility of emission reductions	o	+
Comparison with other emission reduction activities	-	+
Providing the same opportunities for rich and poor countries	+	o
Providing incentives for good maintenance	-	+

Transaction costs

The transaction cost is composed of the costs of the baseline study, validation, registration, monitoring, verification, and certification. The Customised and Global emission reduction baseline methods both offer savings in the transaction costs when compared with a morecomprehensive baseline setting approach. This is due to the simplification of all of the transaction steps. Since the Global emission reduction is the simplest method it offers the greatest transaction cost savings.

The initial investment for developing standardised emission reduction values is smaller for Global emission reduction values than for Customised emission reduction values. The development of Customized emission reduction values would require additional surveys to be carried out[15].

Monitoring activities would be simpler in case of Global emission reduction values. Checking that SHSs have actually been implemented will be the only step needed in the monitoring process. With Customized approach, additional characteristics will need to be confirmed and monitored. For example, it may be necessary to confirm that system maintenance procedures and performance claims are consistent with what has been reported. In the absence of such monitoring, there will be an incentive to cheat.

Credibility of emission reductions

Given the variation in emission reduction values from the different SHS activities studied, it is evident that a global value will in some cases significantly underestimate actual emission reductions from SHSs and in other cases it will overstate what can realistically be expected. Even though the Customised emission reduction value is much more realistic to individual projects than the Global value, there is still a danger that valuable detail is lost. However, the choice of inputs used in the calculations will serve to reduce the possibility of inaccuracy to a minimum.

[15] It is noted that national/regional baselines may not be more costly to the project developer as long as these studies to determine baselines do not have to be paid for by the project developer. It could be funded by the host country or ODA/GEF money using local research institutes.

At this stage of case study examination there are only three projects with solid, reliable data. Such a small set of data does not allow for rigorous computation. As time goes by and more data are used to calculate the Global figure, it will become much more representative of what actually occurs in widespread installations. It will be important to retain access to individual data points used in the composition of the Global value so that the spread of the data remains transparent.

The Global value ensures that unrealistically optimistic values of carbon abatement cannot be used in project documents, being replaced instead by a single, credible figure. However, project developers may see the Global figure as being on the low side and may view the Customised figure as providing an opportunity to more accurately reflect the emissions abatement anticipated in the case of their particular project.

Comparison with other kinds of emission reduction activities

The Global value, despite its drawbacks, provides a single figure that can be used for comparisons between other carbon abatement methods. While this could be seen as advantageous, certain technologies and applications may not have a single figure for their carbon abatement value. Furthermore, it might be imprudent to provide a single figure that could be taken out of context and compared unfavorably to other, larger magnitude carbon abatement projects in a particular region. It may be the case that the Customised emission reduction value would provide the basis for a fairer comparison.

The method of calculating the Global figure was arrived at by reviewing a small number of SHS projects and market activities which encompass different characteristics and represent a fairly large percentage of installed SHSs to date, worldwide. This was felt to be the most appropriate method within the context and timeframe of the project. However, since there are alternative methods, there may be dispute from interested parties that may want the figure to be higher or lower depending upon their motivations. It is therefore of critical importance to obtain consensus from interested parties.

Providing the same opportunities for rich and poor countries

Since the Global emission reduction value will result in all SHSs having the same CER value, it will provide a proportionately greater benefit to SHS users that would have lower than average emissions abatement; these will tend to be households with a lower than average pre-SHS energy consumption. These would tend to be poorer households that could be represented in greater numbers in poorer countries. Alternatively, if the Customised emission reduction value is used for a country such as Swaziland or Nepal (both of which have low energy consumptions) there may not be enough motivation for installing SHSs under the CDM as their carbon abatement potential is not great. The environmental impact of over crediting some systems would be balanced out by under crediting others. Of course, some might see this as an unfair transfer payment from the comparatively wealthy segment of the rural poor to the poorer rural poor.

Providing incentives for good maintenance

It is felt that the maintenance schedule adopted is determined to some degree by the method of system financing and delivery. Fee-for-service and credit sales place some burden on the system provider (or an interested third-party finance entity) to ensure that the system performs adequately. In cash markets this burden will be on the end-user (who also is the main beneficiary of such maintenance). This will be recognised and rewarded in the Customised approach but not in the Global value. Furthermore, regardless of the method of system financing and delivery, the Customized approach can be used to recognise and encourage good system performance.

6. FINDINGS AND RECOMMENDATIONS

Solar home systems are in need of a streamlined CDM process
Complicated CER calculation procedures and overly burdensome information requirements could add to the cost and difficulty of CDM participation for SHS projects and therefore reduce net CER value. Likewise, arduous processes for additionality demonstration could make it very difficult for SHS projects to participate in the CDM and thus have the effect of excluding a category of activity that seems highly consistent with the CDM's overall objectives.

Streamlining SHS participation in the CDM could help to mobilise capital in order to overcome finance barrier for SHS businesses and the first-cost barrier of SHS users. Moreover, by helping to gain government attention and perhaps policy support for SHS activities, participation in the CDM could add value beyond the generation and sale of CERs.

Evidence from implemented SHSs present a significant range in emission reduction figures
The present study has analysed emission reduction from implemented SHSs to find out what the range in emission reduction figures is and what the causes of these differences are. It appears from the eight case studies that a large range of emission reduction figures for individual SHSs. Average emission reduction figures for typical 50 W_p systems varied between 88 and 758 kg CO_2 per year. Average emission reduction amounts to 275 kg CO_2 per system.

Differences in kerosene substitution are the primary reason for differences in emission reduction figures from SHSs
The differences in emission reduction are primarily caused by differences in energy substitution effects. The most important factor determining emission reduction appears to be initial energy use that can be substituted for by SHSs. The contribution from kerosene, previously used for lighting purposes, gives the largest contribution to emission reduction. Replacement of central battery charging, candles, dry cell batteries and generator also contribute to emission reduction.

Emission reduction calculation methodologies in case studies showed differences
All case studies estimated emission reductions from substituted energy use. However, to a certain extent differences in emission reduction figures originate from differences in emission reduction calculation methodologies. It appears that most of the case studies have neglected replacement of energy carriers, other than kerosene. Further, most case studies assumed a 100% or near 100% availability of the SHS. One case study claimed emission reduction from the project's contribution to the future SHS market in the region. Only one study corrected for life cycle emissions from the SHS.

A standardised yet comprehensive way to calculate emission reduction gives a comparable range of emission reduction figures
When the case studies' emission reduction is recalculated based on a standardised yet comprehensive calculation method, the range of emission reduction figures remains similar. The resulting calculation gives average annual emission reduction values of 220 kg CO_2 for a typical 50 W_p system.

Solar home systems usually have a strong case with respect to additionality
There are a number of specific barriers, which limit the development of the rural, off-grid SHS market. These barriers include lack of medium-term financing available to enable consumers to repay the high initial cost of PV systems over time, lack of availability / supply of PV products and systems to rural customers, very limited consumer awareness of the benefits of SHS among

non-users, a lack of managerial and technical skills among many companies selling and installing PV systems, policy barriers such as market distortions in electricity tariffs, subsidies for conventional fuels, and high import taxes and duties on PV modules.

The standardised and simplified calculation of emission reduction from SHSs can be linked to different levels of aggregation
With the evidence from case studies as a basis, ideas have been generated regarding how to standardise emission reduction calculations from SHSs. Two options for standardisation have been analysed:
- Global emission reduction values. This involves one figure for emission reduction per typical SHS, which only may differ for different system sizes.
- Customised emission reduction values. Then, standard emission reduction figures differ e.g. per country or region, per institutional setting.

Initial development is easier for global emission reduction figures than for customised emission reduction figures
The initial investment for developing standardised emission reduction values is smaller for global emission reduction values than for customised emission reduction values. It is illustrative to note that the development of customized emission reduction values would require additional surveys to be carried out, while a conservative global value for emission reduction can already be quantified at 200 kg/CO_2 per year.

Annual transaction costs are lower for global emission reduction figures
Monitoring activities would be simpler in case of global emission reduction values. Checking that SHSs have actually been implemented will be the only step needed in the monitoring process. With customized approach, additional characteristics will need to be confirmed.

Credibility of emission reduction is higher for customised emission reduction figures
Given the variation in emission reduction values from the different SHS activities studied, it is evident that a global value will in some cases significantly underestimate actual emissions reduction from SHSs and in other cases it will overstate what can realistically be expected. Customised emission reduction values are much more realistic to individual projects than the global value, providing an incentive to set up SHSs in a manner that maximizes their emission reduction benefits.

Start with global emission reduction figures and later customise
Ultimately, baseline approaches must address the tension between two fundamental objectives: maximising environmental integrity (by minimising unwarranted credits) and maximising investment in good CDM projects (by minimising transaction costs and crediting all additional projects). It is suggested that the 'reference manual for emission reduction activities' start working with global emission reduction figures, to then evaluate experiences and decide either to gradually introduce customised elements when more survey information becomes available or to continue with periodically updated global emission reduction figures.

The design of CDM programmes can also contribute to a streamlined CDM process
Finally, it is noted that streamlining does not only involve the development of a standardised approach for estimation and monitoring of emission reductions. It can also be very much influenced by the way national and multi-national CDM programmes are set up, with regard to both the clarity of rules and ease of participation.

ANNEX A CASE STUDY QUESTIONNAIRE

The questionnaire is a tool to examine elements that have gone into baseline calculations for SHS case studies linked with climate change mitigation (e.g., estimates of historic energy use from households surveys and calculations, estimates of comparative upstream emissions, etc.). The project team used the questionnaire to make the SHS case study reports[16].

The questionnaire has been structured in accordance with new operational guidance documents for setting up baseline studies that were developed for the recently started Dutch JI programme ERU-PT[17]. The basis of these guidelines of ERU-PT is that every project has to contain the same steps in a transparent matter. These steps also appear in this questionnaire.

1. Project characteristics

For the SHS cases the following issues could be included (not necessary to include all aspects of annex A – only those that provide information to draw lessons relevant for the baseline study):

- General project information presented.
- Objective(s) of the project clearly described.
- Description of the SHS(s) used in the project, including information on:
  - Wp;
  - type of panel: amorphous silicon, multi-crystalline silicon, and/or single-crystalline silicon
  - quality/is it a certified system
  - type of battery: automotive-type lead-acid; deep-cycle lead-acid; or 'other'
  - number and type of lights
  - other components
- Number of SHS installed.
- An overview of SHS project and market experience in the region to put SHS activities into context.

2. Description and determination of GHG sources and system boundaries

- Was a qualitative description of the (life cycle) emissions from the SHS project given?
- Were the emissions from the SHS project quantified?
- Were the emissions embedded in the module considered?
- Were emissions embedded in the batteries considered?
- Were emissions in the other systems components considered?
- Was the expected lifetime of the system components specified?
- Were the system boundaries clearly defined ? Where were they placed?
- A quick screening might show that the panel and batteries dominate the GHG emissions (>90%). Therefore the other components might be neglected
- Is information available for the specific case?

[16] The case studies can be downloaded from http://www.ecn.nl/unit_bs/kyoto/mechanism/cdmshs.html.

[17] Ministry of Economic Affairs, Operational guidelines for baseline studies, validation, monitoring and verification of Joint Implementation projects, May 2000, htttp://www.senter.erupt.

3. Current situation – description and, if possible a quantification

- Energy use and expenditures of the households with different average income levels which are targeted to participate in the project - preferably divided by income group or based on the average household.

Utility/household	No. of hours/day	Energy source, e.g:	Monthly or annual energy consumption	Monthly or annual energy costs
Lights,		Kerosene, candles, etc		
Radios		Dry batteries		
TV		Battery charging		

- Distance to grid.
- Population density (remoteness).
- Adequacy of current situation.

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

4A. Project specific factors

- Quality of the system.
- Adequacy of system design to users' preferences (e.g., do the systems include enough lights for their size and their users' preferences; a 50 W_2 SHS with just 2 lights probably won't displace all kerosene lighting in households that used 3 or 4 lamps before the SHS).
- Quality of installation (self service versus organised installations).
- Maintenance (Are maintenance technicians available locally? Are they trained?).
- Adjustments and replacements of spare parts (For programs providing up-front equipment subsidies, can users afford replacement batteries and other replacement parts; if not, are other provisions made for parts replacement?).
- Theft.
- Type of financing and delivery mechanisms used (cash sales, credit sales, fee-for-service).
- Type and level/percentage of SHS subsidy (i.e., equipment 'buy-down', interest rate subsidy, etc.).
- Satisfaction of the end-users about the system and income (factors that determine whether end-users are willing to pay for SHS services).

4B. External Factors

Kerosene subsidies:

- Income development
- (plans for) grid extension
- Legal aspects
- Socio-economic developments
- Demographic developments
- Others.

5. Identification of baselines and selection of most likely baselines

- How many baseline options have been considered (forward looking/backward looking)? (preferably about 5 baselines have to be considered)
- Which ones?
- How was the selection made?
- Do you believe this was an appropriate baseline, and how could it be improved?

6. Estimation of energy services provided

- Has an estimate been made of the energy services that will be delivered by the SHS and its development over the time (in Ah/day).
- Which factors have been considered:
  - No. of households
  - System factor
  - Part of the system that fails (which part)
  - Entire system fails
  - System down (user doesn't pay)
  - Life time of system components (panel, battery, other components neglectable) Maybe this should go up in question 2 under.

7. Emission of the project

- How has the LCA been carried out – what were the assumptions? I think it would be helpful add a question, here or someplace else, asking whether any kerosene lighting is expected to continue once the SHSs are installed. If so, how much?

8. Emissions of the baseline

- How was the calculation structured?
- What values have been used?

The generic data have to be set on the conservative side. The project developer could subsequently prove that the project performs better (this is the approach usually applied by validators).

9. Determination of crediting time

- What lifetime and crediting time were applied?

10. Estimation of the emission reduction

(= emissions of the baseline minus the emissions of the project).

11. Evaluation of the 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.).
- Confirm that the project would not be undertaken with ODA sources as CDM projects should be additional to ODA.
- Conclude on the additionality of the project.
- How do you see this for future projects?