Could carbon financing appreciably accelerate the diffusion of Solar Home Systems?

Robert F. Lee, *Alternative Energy Development, Inc.*
Ian Simm and Bruce Jenkyn-Jones, *Impax Capital Ltd.*

Task manager: Charles Feinstein, Lead Operations Officer,
UNDP/World Bank Energy Sector Management Assistance Program

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Summary

Solar home systems (SHS) have become significantly less expensive over the past decade and are now within the reach of higher income rural households throughout the developing world. Forecast near-term cost reductions, due to learning and scale economies, appear poised to make SHS a cost-effective and affordable power source for millions of rural households that do not have access to grid electricity. Under current conditions, modest price reductions can substantially accelerate SHS markets in developing countries. Recent experience of the Photovoltaic Market Transformation Initiative (PVMTI) is a case in point. With PVMTI support (financial support primarily low-cost debt, but also partial guarantees, equity, and grant, and technical assistance), potentially 13.5 MWp of PV business ventures that were not viable without external support were made financially viable in India, Kenya, and Morocco. This PVMTI support represents approximately 7 to 10 percent of total installed costs (assuming installed cost of $10/Wp) or $0.7 to $1.0/Wp.

Even with conservative assumptions, the value of carbon emissions from kerosene lighting that would be displaced by solar home systems equals or exceeds PVMTI levels of support. Experience shows that a typical SHS can be expected to displace, on average, 1/3 liter of lighting kerosene daily in rural households. Valued at $10 to $30/t Carbon (predicted trading range), this carbon emissions reduction represents $0.33 to $1.00/Wp. ***With initial PVMTI experience as a guide****, if effectively and efficiently delivered to SHS enterprises,* ***carbon financing could appreciably accelerate the diffusion of SHS among rural households in the developing world****. Carbon financing could make an even larger impact if funds were allocated to projects with the highest kerosene displacement potentials or if carbon credits are able to secure a high value. Carbon financing support of $0.33 to $1.00/Wp for solar home systems would be equivalent to nearly one to three years of expected cost reductions in manufacturing learning curves.*

Carbon financing would be far less effective if it is assumed that a solar home system is to displace a small diesel electric generator. This is because under reasonable assumptions, the carbon emissions from a small diesel generator meeting lighting needs are only 1/2 to 1/3 of emissions from kerosene lighting.

Introduction

To date, photovoltaic solar home systems (SHS) have only marginally penetrated the rural areas of developing countries. High initial costs and a number of other factors have limited diffusion. Nonetheless, installed costs of SHS have declined between 30% and 50% over the past 5 years. This trend is forecast to continue as manufacturing volume grows over the next five years (see Annex II for a summary of SHS price trends and forecasts). At current installed costs of US$ 10-17/Wp, solar home systems are now within the reach of higher income rural households in many regions of the developing world. It appears likely that as production costs decline, solar home systems will become an increasingly affordable power source for millions of rural households that do not have access to grid electricity.

This paper assesses whether or not carbon financing should be directed toward solar home systems. Two related questions arise. First, does SHS represent a cost-effective technology from a carbon emissions reduction perspective? We assess this by presenting our analysis using values in the range of $10 to $30/t Carbon for carbon credits, which is at the predicted price range for carbon by the first commitment period of the Kyoto Protocol (2008-2012). Second, could carbon financing appreciably accelerate the diffusion of solar home systems? We are able to approach this question using the experience of a recent initiative as a guide. Our analysis shows that in addition to SHS being a cost-effective option for reducing carbon emissions, the diffusion of SHS to meet rural needs in the developing world might be substantially accelerated by carbon financing.

An Assessment of the PVMTI Deals

Under the on-going PVMTI project (See Box 1 and Annex V for more information), incremental financing with PVMTI funds (primarily low-cost debt, but also may include partial guarantees, equity, and grant on a project specific case) has made PV businesses viable in India, Kenya, and Morocco. A review of 10 PVMTI deals to date shows that in *ex ante* calculations direct financial support of $0.10 to $0.62/Wp based on net present value equivalent of all PVMTI concessionary support (low-cost debt, guarantees, equity, and grant) will allow PV businesses to achieve viable financial internal rate of return (FIRR) of all equity resources (i.e., project sponsor, PVMTI, and others). The weighted average direct support for the 10 deals was approximately $0.34/Wp. Table 1 shows the range of PVMTI financial support to the PV businesses. See Annex IV for an assessment of the cost of carbon abatement for PVMTI deals.

Table 1 PVMTI Deals and Investment Support

PVMTI Deals	*FIRR without PVMTI support*	*FIRR with PVMTI support*	*Planned Installed Capacity (kWp)*	*NPV of PVMTI Support ($ mil.)*	*NPV of PVMTI Support ($/Wp)*
RQDH	10%	16%	2,672	1.25	0.47
RGZJ	11%	16%	2,188	0.55	0.25
RGDK	14%	19%	3,074	1.07	0.35
ZPTZ	11%	18%	955	0.46	0.48
ZCKH	12%	17%	617	0.38	0.62
LTQZ	10%	15%	455	0.14	0.31
JBAB	7%	10%	825	0.21	0.25
JBAR	7%	15%	410	0.20	0.49
JBAJ	10%	17%	620	0.19	0.31
RQLN	15%	20%	1,838	0.19	0.10
Total and Average Support			**13,654**	**4.64**	**0.34**

Notes: FIRR – Financial internal rate of return
NPV – Net present value

The direct financial support provided to PV businesses does not include the technical assistance activities and project execution costs (identification, structuring, due diligence review, and monitoring of deals as well as other fund management costs) associated with the PVMTI project.

When technical assistance and project execution costs are included, the average total PVMTI support for the projects to date is approximately $0.7 to $1.0/Wp.

This recent experience shows that under current conditions, modest price reductions can substantially accelerate SHS markets in developing countries. For these ten projects, PVMTI support made the difference that allowed each project to proceed. PVMTI represents a small share of total installed costs, approximately 7 to 10 percent of average total installed costs assuming installed cost of $10/Wp. Yet, in each case the small level of support was enough to improve financial rates of return to make relatively large projects viable.

Box 1: GEF/IFC-supported Photovoltaic Market Transformation Initiative

The Photovoltaic Market Transformation Initiative (PVMTI) is a strategic intervention to accelerate the sustainable commercialization and financial viability of PV technology in the developing world. PVMTI will use up to $30 million in funds provided by the Global Environment Facility (GEF) to provide concessional financing of private sector PV market development projects in India, Kenya, and Morocco. It is expected that approximately $13.5 million of funds recovered from investments and portfolio earnings will be available for repatriation to the GEF by the end of the 10-year operation of PVMTI.

Of the GEF funds, $15 million is allocated for project financing in India, with $5 million each allocated for Kenya and Morocco. The remaining $5 million will be used for technical assistance and project execution. Approximately 4 to 7 sub-projects are expected in each country and funds placed in individual sub-projects are expected to range from $500,000 to $5 million. IFC will consider investing its own funds on a case-by-case basis in a limited number of PVMTI sub-projects which meet IFC's requirements for commercially viable investments. Additional co-financing of $60-90 million by sub-project sponsors and other sources (including commercial banks) is expected to result in total project costs of $85-115 million.

PVMTI is expected to have a definitive impact in increasing sales and assuring the financial viability of a number of "beacon companies" providing successful and replicable examples of good business and technical practices. The impact in each of the three national markets is expected to be significant, with sales growth over the base case ranging from 33% in Morocco to 55% in India and 66% in Kenya, and a world market increase of 5% over the life of the project. These incremental, but demonstrable, effects on reducing barriers to market growth and availability of capital are expected to accelerate market dissemination and improve the attractiveness of the sector to commercial finance.

PVMTI-supported projects will be designed by private sector companies or consortia and submitted in response to a broadly distributed solicitation for project proposals. Financing terms will be flexible, and most investments are expected to request debt at below-market terms. The use of other financing such as partial guarantees, equity, or other instruments will be considered if the benefits justify the additional complexity. Project selection criteria will include the assessment of the proposed financial innovation, degree of financial leverage, likelihood of sustainability and replicability on a commercial basis, and the expected level of market growth. Qualifying projects will be considered for investment on the strength of their proposed business plans (including evaluation of the proposed project's financial and technical viability, and the management capability of the sponsors).

The PVMTI Project Document is included as Annex V of this report.

Potential Carbon Reduction by SHS

Displacement of Kerosene for Lighting

Potential markets for solar home systems are routinely assessed on the basis of a minimum willingness to pay for lighting services as estimated by actual expenditures on kerosene for lighting. But carbon emission reductions are direct function of the quantity of kerosene displaced. Lighting kerosene displaced by 10 GEF and AIJ supported SHS projects are displayed in Table 2 below.

Table 2 Average Kerosene Consumption for Lighting from Various SHS Projects

Projects	*Liters/month*	*Average liter/day*
Argentina GEF	15.2-21.3	0.61
Benin GEF	3.0-11.7	0.25
Burkina Faso AIJ	12.0	0.40
Honduras AIJ	7.6	0.25
Indonesia AIJ	16.4	0.55
Indonesia GEF	15.0	0.50
Peru GEF	7.5	0.25
Sri Lanka AIJ	10.0-13.4	0.39
Zimbabwe GEF	2.8	0.09
Togo GEF	3.0-11.7	0.25
Average Consumption		**0.33**

Source: Kaufman, S., April 1999[1].

While there is a wide range across projects from 0.1 to 0.6 liter/day, the simple average consumption of kerosene for lighting is 0.33 liters/day. Note that 0.33 liters/day is used in the analysis below as a conservative estimate of the kerosene displacement potential for SHS projects. Kerosene displacement may be substantially higher in regions with high rates of kerosene use for lighting, such as in Indonesia or Argentina.

Annual Carbon Emissions Displacement

Actual SHS packages come in a wide range of sizes from as small as 10 Wp to well over 100 Wp. Systems of 50 Wp are a robust and popular choice in many locations. Assuming that a 50 Wp SHS displaces the average kerosene consumption for lighting of 0.33 liter/day per rural household and that kerosene contains 0.68 kg Carbon/liter, a 50 Wp system will, on average, avoid emissions of roughly 82 kg of carbon per year (300 kg CO_2/yr)[2].

This estimated value for CO_2 emission reduction is well within the range of values that have been reported for actual SHS projects. Table 3 lists the annual CO_2 emission reduction per SHS in 8 projects. The annual CO_2 emission reduction potential in the eight projects ranged from approximately 80 to 500 kg CO_2 per year with an average of about 275 kg CO_2/yr.

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[1] Kaufman, S., Calculating, Monitoring, and Evaluating Greenhouse Gas Benefits from Solar Home Systems in Developing Countries, Sunrise Technologies Consulting, April, 1999.

[2] Carbon Savings per year (kg C/yr) = Kerosene Consumption (liters/day) * Carbon emissions from kerosene (kg C/liter) * 365 days/yr.

Table 3 Reported Annual CO_2 Emission Reduction Potential per SHS

Country	*Type of Project*	*SHS Module Size (Wp)*	*Average Kerosene Displacement (l/month)*	*Annual CO_2 Emission Reduction per SHS (kg/yr)**
Argentina	GEF	50-400	15-21	504
Honduras	AIJ (US)	30-60	7.6	246
India	Commercial carbon offset funding	35 (20-53)	10	373
Indonesia	WB/GEF	50	14.3	448 (758**)
Nepal	Government of Nepal	35	4.7	79
Kenya	Commercial cash sales	12-50	9	205
South Africa	Shell/ESKOM fee-for-service	50	8	230 (40***)
Swaziland	IVAM/ECN-Triodos commercial credit	50	4.4	125

* Includes savings of candles and battery charging.
** Includes indirect "programmatic effects."
*** For comparison with grid displacement on a kWh basis.
Source: J.R. Yberma, et. al, Nov 2000.[3]

Note that annual emission reductions from the average SHS installation in Indonesia or Argentina are far greater than similar installations in Swaziland or Nepal. As such, project selection will be a critical factor in minimizing carbon emissions. In addition, the South Africa project shows that far less CO_2 would be displaced if the solar home system displaced highly coal intensive South African grid electricity. This is generally true even for small diesel generators used to power loads at the household level as shown below.

Displacement of Diesel Fuel for Lighting

Specific fuel consumption in small diesel generators varies by application, but generally will be in the range of 0.5 to 1 liters per kWh.[4] It is standard practice to estimate carbon emission reductions by determining how much diesel fuel would have been consumed to provide the same amount of electricity as is generated by the solar home system. Table 4 presents the range of annual carbon emission reductions from a 50 Wp SHS operating in a good (but not the best) solar regime of 4 sun-hours per day when it is displacing a small diesel generator operating at 0.5 and 1.0 liters/kWh. Annual carbon savings from lighting kerosene displacement are also shown for comparison.

[3] J.R. Yberma, et. al., Towards a streamlined CDM Process for Solar Home Systems, ECN, Petten, The Netherlands, Nov 2000.

[4] Specific fuel consumption of 0.5 – 0.6 liters/kWh for small diesel generators is reported in "Photovoltaic Applications in Rural Areas of the Developing World," World Bank Technical Paper No. 304, 1995. Similarly, the Project Brief of a proposed GEF project in Ghana reports that a "load-following free-standing" diesel genset has a specific fuel consumption of about 0.65 – 1.0 liters/kWh.

Table 4 SHS Carbon Savings when Displacing Diesel and Kerosene

Specific Fuel Consumption	*B*	*C = (50Wp*4 sun-hrs/day)*	*D = B*C*365*
liters/kWh	*kg C/kWh*	*Power generation from SHS (kWh/day)*	*Carbon Savings per year (kg C/yr)*
0.5	0.34	0.20	25
1.0	0.68	0.20	50
kerosene (0.33 liters/day)		0.20	82

Sources: World Bank Technical Paper No. 304 and GEF Ghana project brief (see footnote).

While the range of specific fuel consumptions is broad, emissions from a small diesel generator for lighting power are generally much less than emissions from kerosene used for lighting. Even if the SHS were located in an excellent solar regime of 5 sun-hours per day, diesel fuel emissions to match the SHS output would increase by only 25%, still well under kerosene emissions.

Generally, solar home systems will displace two to three times as much carbon when substituting for lighting kerosene than when substituting for small diesel generation. Due to this, the estimate of the potential for carbon financing will focus exclusively on lighting kerosene displacement.

Embodied Energy of PV systems

In determining the carbon emissions reduction potential of SHS projects, the embodied energy of PV systems may need to be taken into account depending on the baseline that is established with respect to the SHS project. The baseline emissions scenario for the project may include the embodied energy of baseline technologies and energy requirements for project installation and maintenance in addition to emissions from baseline project operation.

The embodied energy of PV systems can be presented as the time that will take for the PV system to generate electricity (equivalent energy) that was used in manufacturing the system. This time period is termed energy payback time (EPBT). A generally accepted EPBT for crystalline silicon PV systems is 2-4 years and for thin film modules, the energy payback time is approximately 1-2 years. The energy payback time is dependent on manufacturing technologies, cell efficiencies, and solar insolation of the location where the system is applied. Annex III presents summaries of results of a few recent studies on energy requirements to manufacture PV systems.

An EPBT of 4 years for PV systems is equivalent to emissions of approximately 80 kg of carbon in the manufacture of a 50 Wp system assuming conservative assumptions of 0.2 kWh of useful electricity is generated per day by the PV system[5] and carbon emissions from energy used in the production of PV systems is 1.0 kg CO_2/kWh (coal-based generators)[6]. To offset the 80 kg of carbon generated during PV system production, the carbon emissions offset in the first year of SHS application in rural settings where SHS replaces 0.33 liter/day of kerosene lighting should not be counted. For EPBT that is less than 4 years, the carbon emissions reduction potential of SHS that is not counted should be proportionately reduced.

[5] Assumes that a 50 Wp system converts a net of 4 sun-hrs into useful energy accounting for losses in wiring and storage of electricity.
[6] Emissions intensity for combined cycle natural gas generators is approximately 0.5 kg CO_2/kWh.

Potential for Financing Solar Home Systems with Carbon Credits

As shown above, a typical 50 Wp SHS can be expected to displace 0.33 liters of lighting kerosene daily, and therefore avoid emissions of 82 kg C/year. Over a 20-year operational lifetime, *assuming that the baseline (kerosene lighting) remains unchanged for this duration*, such a system will avoid 1.64 tonnes of carbon emissions. The carbon savings per SHS is directly proportional to the displacement of baseline kerosene consumption. Thus if a given SHS project is undertaken in an area of high kerosene use and displaces, say, 0.5 liter per day, then 2.48 tonnes of carbon would be displaced over 20 years.

It is expected that when the Kyoto Protocol enters into force Parties with high domestic cost for reducing emissions are likely to utilize the flexibility mechanisms of the Protocol to invest in projects abroad to accrue carbon credits to meet their commitments. To gain experience in procuring and trading carbon emission reduction credits, some Parties and private entities have already executed some initial deals. The price of carbon credits for these early executed deals have ranged from $0.6/tC to $23.4/tC. See Annex I for the full list of initial deals, current price indications from active carbon investment funds, and price predictions from analytical models and analyses. From the current price predictions for carbon credits, a reasonable range is $10 to $30 per tonne of carbon[7] including the transaction costs of trading the credits.

A simple sensitivity analysis for an average SHS project, displacing 0.33 liters of kerosene daily, and for a high displacement project of 0.5 liters daily and for carbon credits valued at $10 to $30 per tonne is presented in Table 5 below.

Table 5 Sensitivity Analysis: Kerosene Displacement and Carbon Credit Price

A	*B*	*C = A * B*	*D = C / 50*
Carbon Savings per 50 Wp SHS after 20 yrs (tC)	*Price of carbon credit ($/tC)*	*Carbon Incremental Fund per 50 Wp SHS ($)*	*Carbon Incremental Funding ($/Wp)*
1.64	10	16.4	0.33
1.64	20	32.8	0.66
1.64	30	49.2	0.98
2.48	10	24.8	0.50
2.48	20	49.7	0.99
2.48	30	74.5	1.49

Under the best conditions, carbon financing may potentially contribute as much as $1.50/Wp by displacing a substantial consumption of kerosene lighting per day (0.5 liter/day) and receiving a high price ($30/tC) for the generated carbon credits. This would currently amount to roughly 15% of total installed costs for an average solar home system. Using the more conservative assumptions of kerosene displacement of 0.33 liter/day and a carbon price of $10/tC, the potential

[7] Cost of carbon credits are analyzed in real price terms. This methodology may not be appropriate for assessing short-term carbon credit contracts.

incremental carbon financing of $0.33/Wp is similar to the average direct financial support given to PV business in the PVMTI deals. Using the initial PVMTI experience as a guide, carbon financing could potentially accelerate the diffusion of solar home systems by making currently marginal PV systems and businesses financially viable.

Note, however, that if carbon credits are allowed only for the ten-year period ending in the year 2012, the Carbon Incremental Funding estimates in Table 5 would be cut in half. But even under these circumstances, carbon financing could provide the needed financial support that will allow some PV businesses to become financially feasible.

Minimum Size Required for Carbon Transactions

Transaction costs for administering, monitoring and verifying projects that aim to install and service a large number of solar home systems in dispersed rural settings can be substantial. To keep the share of transaction costs at reasonable levels, most carbon funding organizations require projects to meet minimum size requirements.

For example for projects that submit applications to the Netherlands Emission Reduction Unit Procurement Tender (Eru-PT)[8], the projects are advised to offer a minimum of 136,000 tonnes of carbon to be generated during the Kyoto Protocol commitment period of 2008-2012.

Additionally the Prototype Carbon Fund (PCF) recommends that the value of emissions reductions to be purchased from a project needs to exceed $2-3 million[9] in order to cover the transaction costs of applying CDM and JI procedures. Using the PCF target price for emission reduction (ER) credits of $20/tC, the minimum tonne of carbon that each project needs to offer is 100,000 to 150,000 tonnes.

Assuming that minimum ER credits of 150,000 tonnes of carbon are required per project, a SHS project will need to install approximately 92,000 systems if carbon savings per 50 Wp system is 1.64 tC over 20 years or 61,000 systems if carbon savings per system is 2.48 tC over 20 years.

Total investment required to install 92,000 systems at $500 per 50 Wp SHS is estimated at $46 million while to install 61,000 systems the investment requirement would be roughly $30 million.

Performance of SHS and Reliability of Carbon Emission Reduction Potential

The Netherlands Energy Research Foundation (ECN) and independent experts undertook an analysis[10] of 104 projects in the RSVP[11]-ECN database as well as a literature survey to review the experiences with solar PV applications for households in developing countries. The assessment report concludes that there is currently not enough information available to determine the performance of solar home systems and projects in developing countries.

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[8] See Annex I for more information on the Eru-PT.

[9] Learning from the Implementation of the Prototype Carbon Fund, Prototype Carbon Fund Occasional Papers Series, Number 1, Work in Progress, October 3, 2000.

[10] F.D.J. Nieuwenhout, et. al., Monitoring and Evaluation of Solar Home Systems: Experiences with applications of solar PV for households in developing countries, The Netherlands Energy Research Foundation, September 2000.

[11] The National Renewable Energy Laboratory (United States) Renewables for Sustainable Village Power.

Out of the over 100 projects reviewed by the study, only a few projects have information on the performance of the deployed solar home systems. Table 6 presents the operational status of the SHS of the projects.

Table 6 Operational Status of Solar Home Systems of Solar PV Projects
(Percentage of investigated systems)

<table>
<tr><th>Country</th><th>Operating in Good Condition</th><th>Partly Not Operating</th><th>Not Operating</th><th>Source</th></tr>
<tr><td>Kenya</td><td>60</td><td>30</td><td>10</td><td>(Acker, 1996)</td></tr>
<tr><td>Kenya</td><td>77</td><td>2</td><td>21</td><td>(Hankins, 2000)</td></tr>
<tr><td>Tunisia</td><td>38</td><td>37</td><td>25</td><td>(AME, 1999)</td></tr>
<tr><td>India, RKM</td><td colspan="2">98</td><td>2</td><td>(TERI, 2000)</td></tr>
<tr><td>India, Urjagram ‘93</td><td colspan="2">51</td><td>49</td><td>(Sharma, 2000)</td></tr>
<tr><td>India, Leh</td><td>71</td><td>27</td><td>2</td><td>(Sharma, 2000)</td></tr>
<tr><td>India, Kargil</td><td colspan="2">96</td><td>4</td><td>(Sharma, 2000)</td></tr>
<tr><td>Guatamale, Zacapa</td><td colspan="2">55</td><td>45</td><td>(Alvarez, 1999)</td></tr>
<tr><td>Mexico</td><td>76</td><td>21</td><td>3</td><td>(Huacuz, et. al., 2000)</td></tr>
<tr><td>Kiribati</td><td colspan="2"><10</td><td>>90</td><td>(Wade, 2000)</td></tr>
<tr><td>Average</td><td>55</td><td>20</td><td>25</td><td></td></tr>
</table>

Source: F.D.J. Nieuwenhout, et. al., September 2000.
Note: Different methodologies have been used in different studies to assess the quality of the SHS. Also, the systems had been deployed for different time periods (from less than 1 year to a number of years) when the evaluations were conducted.

From the table above, on average, only 55 percent of the installed systems are operating in good condition. However, the above data is a very limited set of data with respect to the number of SHS that have been deployed globally. The study report estimates that approximately 1.3 million solar home systems have been distributed in developing countries with a total capacity of about 40 MWp.

In the above analysis on the potential for SHS projects to secure carbon financing, we have assumed that all deployed systems of the carbon financed project will operate in good condition for 20 years and the baseline for the project will hold true for the 20-year life of the project as well. In designing SHS projects for carbon financing, project sponsors may need to mitigate against the risk of solar home system failures in the field and changes in the baseline during the life of the project.

Conclusions and Issues

A review of *ex ante* calculations of PVMTI deals to date shows that with small levels of incremental financing (concessionary finance and technical assistance to overcome PV market development barriers), properly installed and serviced SHS can compete with current baseline lighting using kerosene fuel. The PVMTI support has been estimated to leverage the installation of more than 13.5 MW of SHS over the next 7 years. At an installed cost of $10/Wp, the incremental financing is approximately 7 to 10 percent of $135 million investment in SHS.

The current analysis has shown that even with the use of conservative assumptions of 0.33 liter per day of kerosene lighting displacement by a 50 Wp SHS, PV businesses may be able to leverage a similar amount of carbon financing with reasonable assumptions on carbon prices at $20 to $30 per tC.

The viability of carbon financing for SHS is very sensitive to: the baseline carbon emissions (e.g., current consumption of kerosene and other fuels for lighting by rural households); transaction costs of establishing a credible baseline and for monitoring and verifying accrued carbon credits for likely large projects of 60,000 to 100,000 systems; the value of carbon credits, and the number of years that the carbon credits can be claimed.

The baseline consumption of kerosene and other fuels for lighting depends on a number of factors, including household income, the availability of kerosene, and the relative prices of kerosene and other fuels. If the baseline for household lighting is diesel generated power, it is likely that only 1/3 to 1/2 of carbon emissions will be avoided relative to the reductions that could be expected from displacing kerosene for lighting.

An additional key challenge will be to design cost effective methods for constructing baselines and monitoring and verification procedures for SHS projects with very large number of systems potentially installed dispersedly. To minimize the transaction cost of these potential CDM project requirements, a proposal has been put forward to simplify the procedures. The *Proposed Simplified Emission Reduction Process for SHS*[12] recommends that a conservative global emission reduction value of 55 kg C/yr or 200 kg CO_2/yr be adopted as the emissions reduction potential for a SHS[13]. Adopting such a rule of thumb is intended to eliminate the requirement to establish a baseline for a SHS project.

An additional issue with SHS projects for carbon financing is the practical challenge of installing a large number of systems (>60,000) in a short period. However, there are currently a few large SHS projects under implementation or planned. The projects include:

- The World Bank/GEF-supported China renewable energy project that plans to install 20,000 50 Wp SHS in the first year, 40,000 in the second year, 60,000 in the third year, and 80,000 in the fourth year for a total of 200,000 SHS;
- Three projects in Morocco with PVMTI support that intend to deploy an average of 50,000 50 Wp SHS per project over a period of 5 to 7 years;
- A project by Shell and ESKOM in South Africa that intends to install 50,000 systems; and

[12] J.R. Yberma, et. al., Towards a streamlined CDM Process for Solar Home Systems, ECN, Petten, The Netherlands, Nov 2000.
[13] The value is based on a review of calculated emissions reduction potential of eight SHS projects.

- The GEF-supported Argentina Renewable Energy in the Rural Market project that plans to install 65,000 SHS.

Compared to other renewable energy and other options that will also reduce carbon emissions and sell its credits, emission credits from SHS can be competitive in attracting carbon financing as long as transaction cost to provide certified credits are kept to a minimum.

This incremental carbon funding will not bring SHS to every un-electrified household but it can increase the market for SHS at the margins. SHS is already affordable to many rural households that currently pay as much or more over a 5-year period for inferior lighting services as it would cost to purchase and maintain a solar home system. The primary barriers to large-scale deployment of PV systems in rural areas are still the availability of financing, the terms of financing, the ability to cover recurrent costs such as replacement of batteries, and the availability of servicing for the SHS.

Carbon financing is not the only way to lower the cost of SHS. There is significant potential to lower costs in all stages of SHS service delivery: in module manufacturing (an addition $1-2/Wp, see Annex II); distribution businesses by improving installation capabilities, servicing, and financing; and in balance of system components, especially batteries. Nonetheless, carbon financing on the order of $0.33 to $1.00/Wp represents one to three years of manufacturing experience on most projected SHS manufacturing learning curves (see Annex II).

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