Green Markets International

Solar Water Heating as a Climate Protection Strategy:

The Role for Carbon Finance

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Table of Contents

Executive Summary

Small-scale renewable energy applications can contribute considerably to global climate protection while playing an important role in improving the quality of life in the developing world. Solar water heating (SWH) is particularly promising; it is one of the simplest and least expensive ways to harness renewable energy and can be comparatively cost-effective for reducing greenhouse gas (GHG) emissions. With financial and other types of support via carbon trading mechanisms, SWH technology could be a valuable component of climate change mitigation efforts.

Water heating typically represents a high percentage of energy consumption in homes and businesses, in some cases 30% or more. When SWH systems supplement or replace conventional water heaters they displace some or all of the fuel that would have been used in those systems. While carbon intensity of baseline fuels for water heating varies, it is generally high in many locations. Consequently, emissions of greenhouse gases and other pollutants are reduced, helping to mitigate climate change while often improving local air quality, and sometimes indoor air quality as well.

Solar water heating contributes to economic development in a number of ways. For example, without the need for highly capital-intensive manufacturing equipment, SWH systems are made in many developing nations, small and large alike. As such, substantial new job opportunities in manufacturing, retail sales, and business administration, as well as system design, installation, and maintenance can result from greater adoption of SWH technology. Additional local economic benefits include substantial savings of conventional fuel costs, with payback periods of three years or less in some locations.

Despite the potential environmental and economic benefits of widespread SWH use, a multitude of barriers still hinder the technology's broader adoption. These generally include high up-front system costs compared to conventional alternatives, a lack of available financing for SWH businesses and consumers, insufficient quality control, and a lack of awareness about the favorable lifecycle economics of SWH technology vis à vis conventional water heaters.

Emerging markets for international trade in GHG reduction credits offer important opportunities to overcome barriers and help advance SWH technology. Since global efforts to fight climate change began in earnest, GHG trading has been considered a practical way to control emissions while enabling compliance flexibility and cost efficiency to participants. Today, numerous voluntary and regulatory GHG trading programs are in operation. Furthermore, with the Kyoto Protocol's imminent February 2005 entry into force, the market is now expanding more rapidly than ever.

For developing nations, the Kyoto Protocol's Clean Development Mechanism (CDM) provides the opportunity for carbon trading to support environmental protection and economic development. The CDM enables trade in GHG reductions between developing and industrialized nations for activities that contribute to sustainable development. With

stringent project review and verification requirements and laborious procedures structured to safeguard environmental objectives, participation in the CDM can be arduous and costly, especially for less developed countries that are more likely to utilize low volume, small-scale projects. In response, the CDM incorporates special rules for small-scale project developers that are designed to enhance the possibility for their participation.

Through the lens of six case studies of CDM-eligible countries with active solar water heating markets – Barbados, Brazil, China, India, Mexico, and South Africa – the authors find that revenue from the sale of Certified Emission Reductions (CERs) can potentially make a meaningful contribution to projects involving SWH technology. Using conservative values of US$5 per ton CO_2 and a 10-year crediting period, the authors find that projects in carbon intensive areas could generate revenue equal to over 10% of a SWH system's original cost based on undiscounted revenue flows. With higher carbon prices and longer crediting periods, the potential contribution could be far greater, even when revenue streams are discounted significantly.

Emission reduction revenue can help to surmount a multitude of barriers for SWH technology. Foremost, carbon finance can help to increase system affordability to end-users and enhance the viability of SWH projects and businesses. Financial arrangements that address constraints on SWH affordability, such as third-party financing and fee-for-service operations, could gain substantially by leveraging underlying and additional finance where project participants establish emission reduction purchase agreements with creditworthy CER buyers.

Carbon trading can also help to overcome institutional, technical and other barriers to the development of SWH markets. In this context, SWH projects could potentially use carbon reduction revenue for market development, training, awareness raising, and other activities to overcome barriers that constrain broader SWH dissemination, such as the establishment and enforcement of quality standards.

Bundling small-scale projects can help address the transaction costs associated with CDM participation and enable the attainment of common minimum size requirements. At the time of this report's publication, there were still no precedents where bundled projects involving SWH applications had completed validation for the CDM, but some projects were working their way through this process. As precedents are set, this will help to facilitate similar initiatives.

This research provides the basis for two overarching conclusions: 1) solar water heating can contribute substantially to carbon abatement while supporting the achievement of economic development goals, and 2) carbon finance can help overcome barriers to the broader adoption of solar water heaters.

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Abbreviations Used

CDCF	Community Development Carbon Fund
CDM	Clean Development Mechanism
CEF	Carbon emission factors
CER	Certified Emission Reduction
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COP	Conference of Parties
DOE	Designated Operational Entity
DNA	Designated National Authority
GEF	Global Environment Facility
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
LDC	Lesser developed country
LPG	Liquefied petroleum gas
MNES	Ministry of Non-Conventional Energy Sources (India)
NGO	Non-governmental organization
NO_x	Nitrogen oxides
PCF	Prototype Carbon Fund
PDD	Project Design Document
SO_2	Sulfur dioxide
SSC	Small-scale
SSN	SouthSouthNorth
SWH	Solar water heaters/Solar water heating
UNFCCC	United Nations Framework Convention on Climate Change

I. Introduction

Renewable energy sources have proven their ability to contribute substantially to global climate protection efforts and can play a vital role in helping to meet rapid growth of energy demand, supporting economic development in developing nations without increasing atmospheric greenhouse gas concentrations. As this paper explains, international trade in greenhouse gas emission reduction credits can help to catalyze new renewable energy projects and stimulate markets for sustainable energy technologies.

With over 45 existing, planned, or proposed markets established for the exchange of GHG emissions allowances and reductions credits, carbon trading has become an accepted tool for local, national, and international programs to limit GHG emissions. Many governments and corporations have already traded millions of tons of carbon, resulting in significant global GHG emission reductions and cost savings for the parties involved. For developing nations, the emerging carbon markets have created opportunities to help catalyze local clean energy projects.

Solar water heating (SWH) is one of the simplest and oldest ways to harness renewable energy and can contribute both to climate protection and sustainable development efforts. Solar thermal technology has existed since at least the time of the ancient Greeks, who designed their homes to capture the winter sun. Today, the global SWH market is growing rapidly. China's market, by far the world's largest, has increased dramatically over the past 20 years, with 40 million square meters (m^2) of total installed capacity in 2002.[1] Over one-third of homes in Barbados are equipped with SWH systems, and in India, SWH is considered among the country's most commercialized renewable energy technologies. Increasingly, hot water is seen as a fundamental aspect of a healthy and hygienic life, and demand for it is growing steadily.

Despite recent growth of the SWH industry and mature markets in several countries, there are still substantial barriers to additional SWH technology diffusion. The most pervasive relate to the lack of established or accepted methods to address up-front costs, and often policy, promotion, or technology failures. SWH markets tend to suffer where technology costs are high and where electricity costs, or other conventional water heating fuel costs, are low. All too often, the measures needed to support demand growth, such as public awareness campaigns, equipment quality standards, and initiatives to increase private sector capacity, are inadequate.

This paper examines the contribution that SWH can make to carbon abatement in several developing countries that are eligible to participate in major carbon trading programs. It also explores how participation in carbon trading can boost SWH markets. Section II provides an overview of international carbon trading programs. Section III briefly

[1] The installed capacity of SWH is often measured by the total surface area of the solar collector. A household system is commonly comprised of 1-3 m^2 of collector surface area and a total storage capacity of between 150-300 liters.

summarizes common SWH technologies and markets. Section IV examines the national SWH market situation in six countries and presents estimates of carbon displacement under the different baseline conditions. Section V examines ways that SWH markets can benefit from carbon finance. Section VI provides a summary of conclusions.

II. Carbon Trading: Common Exchange Mechanisms and Rules

The concept of international trade in greenhouse gas reduction credits has existed since at least the mid-1980s. The United Nations Framework Convention on Climate Change (UNFCCC) in 1992 formally recognized this possibility, and the Kyoto Protocol in 1997 laid the groundwork for three market-based mechanisms: International Emissions Trading, Joint Implementation, and the Clean Development Mechanism (CDM). Numerous voluntary and regulatory programs to control GHG emissions now allow emissions trading as a way to provide market participants flexibility in meeting their reduction commitments. For developing countries, the CDM is arguably the most important carbon trading scheme at the international level. The CDM is designed to help industrialized countries reduce the cost of meeting their emissions targets by taking advantage of less expensive opportunities in developing countries through activities that contribute to sustainable development goals. Of the three flexibility mechanisms established by the Kyoto Protocol, only projects registered through the CDM are able to accrue CERs prior to the first commitment period.

A. Overview of global carbon markets

Expectation of the Kyoto Protocol's entry into force has been a primary driver of the international carbon markets for the past several years. At the same time, uncertainty about how, when, and if the Kyoto Protocol would enter into force has hindered wider expansion of carbon exchange mechanisms. For this reason, the market for carbon emissions reductions has remained fairly small, but as local, national, and international programs to limit GHG emissions have started to take hold, the market is growing. Between 2002 and 2003, the volume of carbon reduction trades doubled. Analysts estimate that over 300 million tons of project-based carbon emission reduction credits have been traded since the market's inception (Lecocq 2004). Following the Kyoto Protocol's February 2005 entry into force, the pace of market expansion is almost certain to increase rapidly. By 2010, some observers estimate that market participants will be trading an average of 250 million tons of CO_2-equivalent (tCO_2e) annually (Haites 2004).

A small handful of participants have dominated the carbon reduction market, but a growing number of public and private entities are now entering the market, especially as the requirements of regulatory regimes such as the European Union's Emissions Trading System (EU ETS) and the Kyoto Protocol gain clarity and the compliance dates draw near. A range of players are now active in the GHG reduction market, including parties buying emission reductions for compliance under Kyoto and other mandatory reduction programs and those participating in voluntary trading programs. Programs designed by emission reduction buyers to finance climate protection and development projects under the rules of the Kyoto Protocol include, among many others: the World Bank's Prototype Carbon Fund (PCF) and Community Development Carbon Fund (CDCF) and the Dutch Government's GHG emission reduction procurement programs. Other market programs are designed to operate outside the purview of the Kyoto Protocol on a voluntary and regulatory basis, including the US-based Carbon Trust of Oregon and the Chicago Climate Exchange, among numerous others.

Over the past several years, prices of CO_2e have ranged from a few cents a ton to about $10 per ton (US dollars used throughout, unless noted otherwise)(Lecocq and Capoor 2002); prices for project based emission reductions in 2003 tended to be in the range of $2-$6.50 per ton of CO_2e (tCO_2e) (Lecocq and Capoor 2003). Many CDM and EU ETS transactions during 2004 have been reported in $5 - $10 per tCO_2e range,[2] and observers expect prices to increase as the EU ETS and Kyoto Protocol emissions limitation requirements take effect over the next few years. As the markets mature in the face of clearer rules for GHG emission constraints, contract terms are becoming more standardized, trade volumes are increasing each year, and more players are entering the market, including businesses that have traditionally not taken an interest in environmental matters (PCF*plus* 2002; Point Carbon 2003).

Until recently, Lesser Developed Countries (LDCs) have been almost entirely absent from the emission reduction credit markets. LDCs are challenged in their quest to join the carbon market on many fronts. Obstacles include their limited ability to produce credits in high volume, high transaction costs associated with low economies of scale, a lack of large and rapidly growing sectors that would typically attract private investors, higher real and perceived risks of investment in many countries, and long lead-times to prepare projects due to inadequate in-country institutional capacity. Also, until recently, there have been relatively few mechanisms designed to meet the specific needs of LDCs and the small-scale projects that tend to be the most common in those countries. Presently, private sector actors are much more likely to purchase emissions reductions either through large projects in Asia and Latin America, either directly or through private-public partnerships like the PCF, where risks and transaction costs can be dispersed across a large portfolio rather than concentrated in one or two projects in smaller developing countries.

The World Bank's CDCF was developed as an instrument to help communities in LDCs access investments in renewable energy and other clean technology via the carbon markets. To do so, the CDCF purchases emission reductions from projects in LDCs that meet the regulatory requirements of the CDM while reducing the bureaucratic hurdles that lead to the high transaction costs that small scale prospective CDM projects often face. To reduce costs and risks, the CDCF works with local financial institutions, micro-credit institutions, cooperatives and NGOs.

[2] Point Carbon and other sources periodically report on prices and volumes of CDM and EU ETS transactions.

B. Rules for carbon trading under the CDM

The CDM was outlined in Article 12 of the Kyoto Protocol, which detailed the basic participation requirements, including that eligible reductions must be: certified by independent Designated Operational Entities (DOEs); approved by each party involved; involve real, measurable, and long-term climate change mitigation benefits; and be additional to what would occur in the absence of the certified project activity. The 2001 Marrakech Accords, signed during the seventh Conference of Parties to the UNFCCC (COP-7), finalized many details regarding CDM participation. These include how projects need to comply with the CDM's sustainable development criteria, the project approval process, performance monitoring and verification, and the process for issuing Certified Emission Reductions (CERs). Marrakech also created the CDM Executive Board, which is the supervisory body of the CDM and is ultimately accountable to the Conference of the Parties.[3]

According to the Marrakech Accords and other Party decisions, project developers must take the following steps to obtain CDM project status and generate CERs:

1) gain approval of the host country's Designated National Authority (DNA) and affirmation that the project will contribute to the host country's sustainable development goals;
2) obtain authorization from the Party(ies) to the Kyoto Protocol for the voluntary participation of the proposed project participants;
3) prepare a Project Design Document (PDD) detailing the project's activities, proposed baseline and monitoring methodology, crediting period, and information on the project participants;
4) obtain validation of the PDD by a DOE;
5) register the project with the CDM Executive Board; and
6) monitor actual emission reductions achieved and obtain verification from a second DOE, which can be the same DOE that provided validation for qualifying small-scale projects.

Based on a verification report submitted to it by the DOE, the CDM Executive Board will issue CERs for the amount of GHG abatement that occurred during the verification period.

The methodology for estimating the "project baseline" scenario is one of the most important components of a CDM project, and project developers need to document this in a PDD. The baseline is an estimate of emissions that would have occurred in the absence of the proposed project activity. The baseline is used to calculate the quantity

[3] Many sources provide detailed information on the CDM and the process of participating. For example, see the official UNFCCC CDM website at http://cdm.unfccc.int/. Other UN-based and independent sources of information on the CDM include UNDP's CDM page at http://www.undp.org/energy/climate.htm and the International Emissions Trading Association's website: (http://www.ieta.org/). For those seeking guidance on the participation process, helpful resources include the UNDP's "CDM User's Guide" and IETA's "Guidance note through the CDM Project Approval Process" and SouthSouthNorth's CDM toolkit at http://www.cdmguide.org.

of emission reduction credits the project can generate. Project developers must also select a crediting period; according to CDM rules, it can be a fixed period of ten years, or a seven-year period, which can be renewed up to two times, for a maximum of 21 years.

Project design documents must also specify a monitoring and verification plan. These outline: the data used to track and quantify emissions (if any) and emission reductions from the project; the method for collecting data, including quality assurance and quality control procedures; and methods for calculating emission reductions from the data collected, including adjustment for exogenous factors such as weather, production levels, and operating hours. Project participants must monitor activities over the life of the project and periodically arrange for emission reduction verification by an independent party, the DOE, which then issues a verification report. As indicated above, the verification report provides the basis on which the CDM Executive Board issues CERs.

The CDM participation process can be burdensome and costly for any project developer; those operating small-scale (SSC) projects are particularly sensitive to high transaction costs related to the approval process.[4] In light of the special circumstances that small-scale projects bring to bear, such as the important contribution they can make to sustainable development and provision of services necessary for human enrichment, the Marrakech Accords instructed the Executive Board to develop methods to reduce the cost and complexity of CDM participation for projects defined as small-scale. Projects qualifying as ‘small-scale’ under the Marrakech Accords include renewable energy projects with a maximum capacity of 15 MW (or equivalent), energy efficiency improvement project activities that reduce energy consumption by up to the equivalent of 15 GWh per year, and other project activities that both reduce anthropogenic emissions by sources and directly emit less than 15 kilotonnes of CO_2e annually.

As instructed by the Marrakech Accords, the CDM Executive Board established “simplified modalities and procedures” for small-scale projects. These special provisions include:

- a simplified PDD;
- pre-approved simplified and standardized methodologies for determining a baseline and creating a monitoring plan;
- the ability to bundle project activities for the PDD, registration, and verification to reduce administration costs;
- simplified provisions for environmental impact analysis;
- reduced registration fee; and
- an ability to have the same DOE validate a PDD and verify emission reductions for a specific SSC CDM project.

[4] Some estimates suggest that, without special provisions, the transaction costs of CDM participation could easily overwhelm the financial benefits for many small-scale projects. See, for example, IETA’s “Guidance note through the CDM Project Approval Process.”

Pre-approved "standardized" baselines are designed to reduce the high transaction costs associated with the low economies of scale that can cripple small projects.[5] To that end, based on input received from advisory panels, the CDM Executive Board has adopted a set of pre-approved methodologies for setting baselines for several categories of small-scale CDM project activities. These methodologies are presented in Appendix B of the Simplified Modalities and Procedures for Small-Scale CDM Project Activities, which also outlines standardized methods that can be used for project monitoring. To qualify for these standard procedures, in addition to meeting the applicable scale requirements, small projects must indicate why the project activity would otherwise not be implemented due to the existence of one or more of four barriers, as explained below.

Attachment A to Appendix B, Simplified Modalities and Procedures for Small-Scale CDM Project Activities, states that "Project participants shall provide an explanation to show that the project activity would not have occurred anyway due to at least one of the following barriers: (a) Investment barrier: a financially more viable alternative to the project activity would have led to higher emissions; (b) Technological barrier: a less technologically advanced alternative to the project activity involves lower risks due to the performance uncertainty or low market share of the new technology adopted for the project activity and so would have led to higher emissions; (c) Barrier due to prevailing practice: prevailing practice or existing regulatory or policy requirements would have led to implementation of a technology with higher emissions; (d) Other barriers: without the project activity, for another specific reason identified by the project participant, such as institutional barriers or limited information, managerial resources, organizational capacity, financial resources, or capacity to absorb new technologies, emissions would have been higher."

III. Overview of Domestic Solar Water Heating

Domestic solar water heaters for residential and commercial applications are one of the simplest and often among the most cost-effective renewable energy technologies.[6] Using materials that are locally available in many countries, SWH systems can be constructed without highly sophisticated or tremendously expensive manufacturing technology. Yet, their simplicity belies their potential to contribute substantially to global GHG reduction efforts. Today, while billions of dollars are being poured into research and development of highly sophisticated, state-of-the-art energy technologies, solar water heating – one of the simplest and oldest renewable energy technologies – continues to prove its value in many parts of the world.

SWH markets are growing. The European Union consistently exceeds targets for SWH adoption. In Israel, approximately 80% of the residential buildings are equipped with

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[5] Even using simplified procedures, projects must be of a sufficient scale to cover CDM transaction costs, which can still amount to $100,000 or more. Furthermore, many of the fixed costs associated with CDM participation occur up-front, whereas revenue is commonly generated over time from the sale of CERs. Some buyers can assist by advancing payments to cover CDM participation costs and by purchasing a percentage of anticipated CERs up-front.

[6] Solar water heaters engineered for higher temperature industrial applications are usually more complicated, but can also be highly cost effective.

solar thermal systems, and in Turkey, technicians install over 630,000 m^2 of SWH collectors annually. Over 1,000 manufacturers in China service its domestic market, and over 15% of Japanese households rely on solar thermal technology to heat water (ESTIF 2003). Awareness of the benefits of SWH is increasing, and adoption of the technology is expanding in developed and developing countries alike.

A. Technology applications and markets

A variety of conventional manufactured water heating systems are available on the world markets, with local preferences and equipment varying by country and region. These include systems that heat water in tanks using a variety of energy sources such as electricity, piped and bottled gas, and other fuels, and systems that heat water on demand (instantaneous systems) principally using electricity or gas.

For household SWH systems, a few standard designs stand out. The fundamental components of all SWH systems are a solar collector, an energy transfer system and a storage system. Passive "thermosyphon" systems use a natural, thermally-driven circulation process, while active systems use an electric pump to circulate the transfer fluid (e.g. water or antifreeze) through the collector. SWH systems are also either open loop (direct) or closed loop (indirect) systems. Open loop systems circulate water directly through the collector, while closed loop systems use a heat-transfer fluid to transfer heat from the collector to the water in the storage tank. In most developing countries where there are high levels of insolation and little risk of freezing, thermosyphon open loop systems are most common, due to their low cost, simple design, higher efficiencies, and longer life span – all factors that also facilitate local production and ease of use.

The potential market for SWH includes households that have both previously used conventional water heating systems and those that have not had any access to water heating services at all. Those that have had experience with water heating by conventional sources might be attracted to the negligible operating costs of SWH or otherwise interested in the technology. Given the vast numbers of conventional water heaters in use today, this market is potentially enormous. The second category represents a substantial percentage of homes in rural areas of many countries and of low-income homes in some urban and peri-urban communities where the latent demand for hot water services is large. In China, over 200 million people still lack access to a hot water supply, i.e., well over 10% of the population; vast numbers in India reportedly burn biomass to heat water.

With limited access to consumer financing for SWH, up-front payments have been a common mechanism for SWH sales in many countries. However, typical household budgets and lack of accumulated savings among the majority of households in most developing countries severely restrict large capital expenditures. Therefore, the requirement for up-front cash payments limits the SWH market to the wealthiest households or commercial enterprises.

Where available, opportunities for term payments can expand SWH appeal to a wider market and broaden affordability. Consumer loans enabling term payments over a period of years can increase affordability to the point where monthly or other periodic payments are comparable to the cost of conventional alternatives during the loan repayment period. Another approach that has started to emerge in some markets involves system rental or “fee-for-service” operations. In this approach, the implementing company (which could be a utility company, an energy services company, or a SWH business) rents or leases SWH systems, or meters and sells the energy service provided, i.e., hot water. Proponents believe fee-for-service arrangements can substantially broaden markets, making solar hot water less expensive to consumers than conventional alternatives. In the fee-for-service approach, the implementing company’s technicians are responsible for system maintenance.

B. Environmental and health benefits

While the contribution that SWH can make to global climate protection is often overlooked, its potential is considerable. The fundamental reason is that solar thermal energy displaces the need for other heating fuels. The extent of actual emission reductions depends on the fuel source that would be used in the absence of the solar water heating system.

Where SWH systems directly replace conventional water heaters or provide supplementary energy, they displace some or all of the fuels that would have been used in those systems. In many countries, industrial and developing alike, heating water typically accounts for about one-third of a household’s total energy consumption. As indicated in the following section, in India and South Africa, carbon intensive coal-generated electricity is commonly used to heat water and thus carbon abatement from SWH is high. Where oil-generated electricity is used to heat water, the situation is similar. Even in countries such as Mexico where water heaters are fueled by comparatively low carbon energy carriers such as natural gas and liquefied petroleum gas (LPG), carbon abatement from SWH use can still be substantial.

Table 1 illustrates the carbon emission factors (CEF) of various fuels that typically provide the energy to heat water for household consumption. Actual CO_2 emissions will depend on the efficiency of any intermediary energy conversions and of the technology ultimately used to heat water. Where natural gas or coal is used to generate electricity, for example, one must consider the combustion efficiency of the power plants; a standard coal fired plant operates at 30% efficiency. By contrast, a survey of real-world observations and laboratory tests suggests that biomass-burning cookstove efficiency is at most 15% (CookStove.net 2004).

Table 1: Carbon Emission Factors (CEF) for various conventional fuels

Fuel	CEF (tC/TJ)
Natural gas	15.3
LPG	17.2
Kerosene	19.6
Crude oil	20.0
Coal (anthracite)	26.8
Peat	28.9
Solid biomass*	29.9

* The CEF for solid biomass assumes the biomass is harvested unsustainably and therefore is not carbon neutral.

Source: IPCC Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Workbook (Volume 2)

When SWH systems displace fossil fuels, they reduce ambient air pollutants including oxides of nitrogen, carbon monoxide, and often sulfur dioxide, volatile organic compounds, and particulates as well as CO_2. A recent study supported by the United States Environmental Protection Agency found that SWH was among the most cost-effective ways to reduce CO_2, CO, and NO_x in Mexico City residences and businesses (West et al. 2003).

Where SWH displaces fuelwood or coal burning within homes, the health of individuals and the entire household benefit. In many cultures and locations, females are typically responsible for stoking fires and tending to whatever is being heated, such as food, water, fabric dyes, etc. Consequently, they and those in their vicinity suffer inordinately from chronic respiratory disease associated with smoke inhalation. Another important health-related benefit is greater availability of hot water for household sanitary needs. Many common water-borne diseases can be prevented with proper washing, and hot water provides an additional level of disinfection over cold or room-temperature water (UN-HABITAT 2003). Using solar heat and radiation to treat water is also an effective way to minimize exposure to some waterborne microbes, which can cause diarrheal diseases. Even when solar thermal energy is not adequate to purify water, its use will drastically cut down on the amount of conventional fuels needed to reach higher temperatures for sterilization.

In some cases, SWH systems can contribute to broader public health initiatives. In Thailand, farmers use the hot water supplied by SWH systems to extract natural insect repellent from locally abundant herbs. In this context, SWH not only reduces the prevalence of synthetic chemicals in the country's food production, but it also reduces the use of conventional fuels, mainly LPG, that farmers normally would use in the herbal extraction process. Moreover, enabling local firms to produce their own pesticides more cheaply and consistently will reduce the need for imported chemicals (Piyasvasti 2001).

Solar water heaters and their effect on local economic development

Development agencies, organizations in the United Nations system, national and regional development banks, and NGOs have invested in programs to develop SWH markets in various localities around the world. The promise of new markets for locally-made SWH technology and ancillary businesses is a primary driving force for such initiatives. In contrast to wind and photovoltaics, SWH offers substantial employment opportunities to local semi-skilled artisans, both in manufacturing and installation. Indeed, a range of new jobs emerge from manufacturing and assembly, system installation, and engineering to accounting and administration, management, retail sales, and technical services. A South African study found that if the national government implemented more ambitious targets for domestic SWH penetration, over 355,000 new jobs could be directly and indirectly created (Austin et al. 2003).

Local businesses also stand to gain from greater adoption of SWH technology. For example, initiatives in Morocco, South Africa, and Zimbabwe that emphasize the role of SWH for hotels, high rise commercial buildings, hospitals, and other businesses, have found that cost-saving opportunities can be substantial. SWH can also boost local tourism revenues. For example, hotels and resorts in temperate climates can advertise an extended swimming season or hot showers, helping to increase visitation. In rural areas where fuelwood is scarce, yet where tourists demand hot water, SWH can make an important contribution to revenue generation (ESOK 2000; SIDSnet 2000).

Even for a household with modest financial resources, SWH can be a wise investment. Where solar radiation is strong and conventional fuel costs are high, SWH equipment can pay for itself in a relatively short period, with payback periods of three years or less in some situations.

C. Barriers to growth of SWH markets

A multitude of barriers impede the broader adoption of SWH systems in markets around the world. These generally include high up-front system costs compared to conventional alternatives, a lack of available financing for SWH businesses and consumers, a lack of awareness about the favorable lifecycle economics of SWH technology vis à vis conventional water heaters, and a lack of quality control, which often undermines consumer confidence as people associate SWH with mediocre or low quality equipment.

Financial barriers to SWH adoption are most common. In most countries, it is less expensive for homeowners to install standard electric or gas water heaters than to purchase solar heating systems. Low conventional fuel costs can also perpetuate the low demand for SWH technology. Often, governments subsidize the use of electricity and fossil fuels while simultaneously levying high tariffs against imported renewable energy equipment, further marginalizing the technology. Limited capacity in the local private sector to manufacture, distribute, install, and maintain high quality SWH systems, coupled with a dependence on expensive imported systems, virtually ensures that SWH technology costs remain high in many developing countries. In addition, many of those who would consider borrowing money to pay the up-front cost for SWH equipment are often unable to do so, due to the prospective borrowers' limited credit history or the lack of bank personnel's understanding of SWH.

Prevailing institutional practices also commonly hinder growth in SWH markets. With conventional water heaters overwhelmingly dominating the market in most locations, consumers wishing to adopt SWH technology often encounter difficulty in finding retail outlets or system design and installation businesses with adequate knowledge to properly size, install, and maintain solar water heating systems. Linkages between the various parties involved in the SWH industry are often underdeveloped, and there is little or no coordination between the public and private sectors to promote alternative energy technologies.

Rightly or wrongly, SWH systems often suffer from a bad reputation. Sometimes this is a function of the inability of governments to adequately control the quality of SWH equipment in their markets, or of customers to find a satisfactory avenue of recourse when SWH equipment fails. Even where SWH equipment is high quality, there is often a general public perception that SWH technology is inherently flawed and not worth serious consideration as a viable alternative to conventional water heating systems. Low sales volume, the low profitability for dealers of SWH systems, and indifferent public policy encourages the use of sub-standard quality products. This perpetuates the popular notion that SWH systems are inferior products, even where some or most of the available equipment is of high quality.

IV. Solar Water Heating Markets & Carbon Abatement in Six Countries

To better understand SWH market conditions in different localities, as well as the extent of carbon abatement from SWH use and the ways in which carbon finance might help to boost SWH markets, the authors examine residential and commercial markets in six countries where the technology is currently used: Barbados, Brazil, China, India, Mexico, and South Africa. While population size in this varied group of nations ranges from among the world's smallest to its largest, collectively these countries represent a good cross-section of countries eligible for CDM participation.

A. Market summaries

1. Barbados

The SWH systems used in Barbados are usually domestically manufactured thermosyphon systems. Most consist of a flat plate collector and separate tank, though some integrated collector systems are on the market; all are open loop systems. Household systems are typically 300 liters and cost approximately $1,800 each, or $6.00 per liter of capacity (Ince 2000; Sunpower Hot Water Systems). With a Gross

National Income in Purchasing Power Parity (GNI PPP)[7] per capita of over $15,000, many Barbadians are relatively well equipped to pay the up-front costs of SWH systems. Furthermore, affordability is usually not an issue for most buyers of SWH systems who pay income taxes, as they can take advantage of 100% income tax rebate.

To keep costs down, the government offers preferential import tax treatment to local manufacturers for fabrication materials, in addition to the above mentioned 100% income tax rebate to buyers of domestic SWH systems (Ince 2000; Government of Barbados 2001). As a result of these very favorable tax policies, Barbados has one of the world's highest per capita rates of SWH penetration; as of 2001, over 32,000 installed systems provided at least 39% of all households with SWH services (Ince 2000; Jensen 2000; Government of Barbados 2001). This high rate of SWH adoption is due to several factors, including the country's relatively high rate of insolation, extremely high electricity tariffs, and very active government pro-SWH incentive programs.

Despite the robust SWH market, electric systems are still the norm. Almost all of Barbados's 78,000 households are connected to the national grid, which is powered almost entirely by combustion of imported oil (UN-HABITAT 1999; Ince 2000; UNSD 2004). Relative to the global average, electricity tariffs in Barbados are very high, with average rates of around 17.5 cents per kWh; furthermore, electricity prices have been rising at record rates throughout the Caribbean region (Ince 2000; EIA 2004; Guiney 2004).

2. Brazil

Brazil's domestic market for SWH technology is underdeveloped and faces extreme competition from conventional electric instantaneous heaters (*chuveiros*). Despite 20 years of experience and a large network of manufacturers, distributors, and retailers, only roughly 2.2 million m^2 of cumulative surface area is installed in Brazil as of 2002, or only about 1.2 m^2 per 100 inhabitants, vastly less than leading countries such as Israel, Austria, and China. A typical domestic SWH system sold in Brazil is an open-loop thermosyphon design with two to three m^2 of flat-plate solar collectors attached to a 200-liter tank. Prices are moderate, although at around $840 per system including installation ($4.20 per liter) they remain out of reach for the majority of Brazilian households, especially in poorer districts (Schaeffer et al. 2000; Winrock 2002; ABRAVA 2004; Rodrigues and Matajs 2004).

The government does not offer direct subsidies to the SWH industry, but it does offer some tax incentives to those that purchase and install renewable energy technology. In addition, a small number of private lenders offer financing opportunities for SWH system purchases.

[7] GNI PPP reflects gross national income that has been converted into a standardized "dollar" by applying a factor to adjust for purchasing power parity.

Arguably, the largest barrier to more rapid acceleration of the SWH market in Brazil involves cost competitiveness with electric instantaneous water heating technology. Currently, 67% of households use these relatively inexpensive *chuveiros*, which represent up to 24% of the nation's total residential electricity demand. While these systems are quite efficient (they heat water only as needed), their widespread use contributes to peak demand rather than to the base load, driving the need to install additional generating capacity to provide peak power (Rodrigues and Matajs 2004). Therefore, the low initial cost of the *chuveiros* masks the high upstream investment costs associated with their widespread use.

In the face of rising electricity costs and increasing awareness of environmental issues, sales of SWH systems in Brazil are escalating, reaching annual growth rates of 10%. In addition, technological innovation, maturation of secondary and tertiary markets, refinement of equipment standards, and development of a quality testing regime have all contributed to the market's expansion. Nevertheless, despite these promising signals, significant barriers still exist for SWH to compete effectively with *chuveiros*.

3. China

In recent years, China has become the world's biggest producer and consumer of SWH systems. In 2002, production reached eight million m^2 – an increase of 66% over 1999 production levels. With less than 1% of the national SWH production being exported, the accumulated installed area of domestic SWH systems was about 40 million m^2 in China as of 2002 (ESTIF 2003). The majority of SWH systems on the domestic market in China now use vacuum tube collectors, and at an average price of $2 to $3 or less per liter of capacity, these vacuum tube systems are still well below the world average for basic flat plate collector systems (US Embassy Beijing 1998; Hua 2002; Changzhou Skypower Solar Industry Co. Ltd 2003; ESTIF 2003). Flat plate collectors, the predominant technology until the mid-1990's, still represent a substantial portion of solar water heating equipment manufactured and used in China and typically cost around $1.45 per liter of capacity (Hua 2002; ESTIF 2003). Some integral systems with a combined collector and storage tank are also manufactured and used in China, but they are not very popular.

Even with relatively low prices for SWH, however, conventional systems remain the norm. Almost three quarters of all hot water in China is obtained via a manufactured water heater (Brockett et al. 2002). Gas heaters are popular in urban areas, as system efficiencies have improved and as more households gain access to piped natural gas supplies (Hua 2002). In regions that have a strong capacity to generate and distribute electricity, electric water heating systems are common. However, in places where the electric grid is limited, where electricity is particularly expensive, or where natural gas supplies are limited, SWH systems are consequently more popular (Hua 2002).

China's regional and national government agencies have traditionally put a premium on providing natural gas and electricity supplies to the public at low prices (Logan and Dongkun 1999; EIA 2004). However, as a result of an increasing reliance on market mechanisms and aggressive measures to improve air quality, the costs of electricity and natural gas have been increasing in recent years (Sinton and Fridley 2001; Logan and Xiucheng 2002).

Although there are no direct government subsidies for SWH manufacturers or end-users in China, the solar thermal market is on the rise (Xiao et al. 2004). The Chinese government has supported research and development efforts and has also implemented quality control standards for SWH systems (Hua 2002; ESTIF 2003). According to some reports, however, low quality products still proliferate on the Chinese market. Another hindrance to further SWH dissemination is a lack of communication and coordination between manufacturers and the building industry.

4. India

India is well positioned to exploit the vast potential demand for SWH systems, which are already one of the country's most commercialized renewable energy technologies (ESTIF 2003). The quality of SWH equipment is quite high, thanks to the Bureau of Indian Standards, which sets and reviews quality standards (Vipradas 2001). In the household sector, most systems consist of a basic thermosyphon design with glazed flat plate collectors. Some vacuum tube collectors have been introduced, but these imported systems are considerably more expensive than domestically-made flat plate systems (ESTIF 2003). The average cost of a domestic SWH system is around $3.50 per liter of capacity (Reddy 2001; Solarbuzz 2002; ESTIF 2003). One reason for this lower-than-average price is a robust manufacturing base in India that is the direct result of an ambitious effort by the Ministry of Non-conventional Energy Sources (MNES) to boost the SWH industry. Moreover, government subsidies in the form of low interest loans are helping to increase the systems' affordability for middle class buyers (Vipradas 2001; Press Trust of India 2002; IREDA 2004).

In spite of the commercial success of India's SWH industry, with a GNI PPI of only $2,750, affordability remains an issue for vast segments of the population. Most SWH applications in India are in the commercial and industrial sector, and households only account for about 20% of SWH installations (OPET-TERI and HECOPET 2002; ESTIF 2003; Kamal 2004). Furthermore, the level of market development varies greatly by region.

India is a predominately rural country that lacks comprehensive nationwide electric or natural gas distribution. Consequently, over half of all households have no regular access to electricity, and LPG supplies to rural areas can be infrequent and prohibitively expensive (IEA 2002; UNDP 2003). Therefore, in areas where there is demand for hot water services but no electricity, households must rely on non-conventional energy sources, such as dung, fuelwood, or agricultural waste. In many cases, this biomass is combusted inefficiently in an open stove, putting household members at severe risk of respiratory disease (Goldemberg 1996; Reddy 2002; Varughese 2004). In the face of such health risks, people even in desperately impoverished areas have a demand for hot water and have expressed a willingness to pay for it (ESTIF 2003).

Where households are connected to the electric grid, electricity is the most popular energy source to heat water. A UNEP-sponsored survey found that 90% of respondents relied solely on electricity to heat water, and that between 20% and 30% of their electricity consumption goes to heat water (Reddy 2001). Electricity tariffs vary widely depending on local or provincial social, political, economic, and geographic factors (WEC 2001), but overall they are quite low relative to other developing countries, with average rates around 2.4 cents per kWh (WEC 2001; EIA 2004). However, electricity tariffs in India are increasing steadily (Vipradas 2001; ESTIF 2003), which serves to increase the competitiveness of SWH versus conventional electric systems.

5. Mexico

As of 2000, the vast majority of Mexico's 370,000 m^2 of total SWH collector area was installed in hotels, private clubs, and other commercial enterprises to warm swimming pools (CONAE 2002; Buen 2003), with households accounting for only approximately 1% of all SWH installations (Davila 2003). In the Mexican domestic SWH market, simple thermosyphon systems with flat plate collectors dominate. A typical system for a medium-sized household costs roughly $6 per liter of capacity. While multiple factors influence markets for SWH, the relatively low adoption of household SWH systems is primarily a reflection of low levels of public awareness about this option, the technology's up-front cost, perceived reliability problems, a history of low costs of conventional water heating technology and its operation, and a lack of public and private sector measures to advance residential SWH markets in most parts of the country.

In Mexico, natural gas – both liquefied and piped – is the most popular fuel for household water heating. In 1999, the 18 million households in the Mexico City metropolitan area consumed natural gas or LPG at the rate of six million liters per day (World Bank 1999; Quintanilla et al. 2001), nearly half of which was for heating water (Buen 2003). The federal government keeps energy costs to households low through generous subsidies, and natural gas supplies are widely available. In 2001, average natural gas prices were 8.7 cents per cubic meter (Quintanilla, Bauer et al. 2001); LPG prices in that same period were 37 cents per kilogram (CRE 2004). In both cases, these prices are significantly less than the worldwide average (IFS On-Line 2004). Nevertheless, gas prices in Mexico are steadily rising, and the market for SWH is slowly growing (Buen 2003; CRE 2004).

In Mexico, as in many other countries, conventional water heating systems are substantially less expensive than their solar thermal counterparts. A 2001 survey of 11 Mexican solar water heating companies found that average SWH systems for medium-sized households cost roughly $6 per liter of capacity (Quintanilla, Bauer et al. 2001). Few financing opportunities exist for SWH purchases, so low and middle-income households are generally limited in their ability to afford SWH systems. The SWH industry in Mexico also suffers from a lack of coordination between manufacturers, distributors, retailers, technicians, and end-users. The disorganized state of the industry reportedly contributes to poor penetration of SWH technology in the residential water heating market. In addition, the quality of SWH equipment is inconsistent, contributing to the perception that SWH is an ineffective technology. To address these challenges, collaborative private-public efforts are underway to educate policy makers, consumers, and technicians. For example, local and regional governments in the Mexico City Valley Metropolitan Region, in conjunction with the US Environmental Protection Agency, have embarked on an ambitious campaign to improve the area's air quality, in part through greater use of SWH systems (West, Osnaya et al. 2003).

6. South Africa

Blessed with extraordinary solar resources, South Africa has a long history of SWH use. In the modern era, however, the market for domestic solar water heating has largely stagnated while the technology for swimming pool heaters has blossomed (Cawood and Morris 2002; Spalding-Fecher et al. 2002). The total SWH installed capacity is around 500,000 m^2 (DME 2002), including all types. For the domestic (non-swimming pool) SWH market, South African manufacturers produce a wide range of systems, from very basic integral systems that require little plumbing to more elaborate active, split collector systems. The up-front cost of typical residential SWH systems are on par with the worldwide average, with prices ranging from $5.50 to $9 per liter of capacity.

Even though SWH prices in South Africa are competitive from a global perspective, they are still perceived as too expensive for many households. As a result, most residences receive their hot water services from conventional electric systems, as up-front equipment costs are modest and electricity tariffs are exceptionally low, with a national average of roughly 3.9 cents in 2000 (WEC 2001; Cawood and Morris 2002; EIA 2004). However, despite the relatively low cost of owning and operating electric water heaters,[8] many of the country's poorest are still unable to obtain hot water services. Consequently, many heat water on inexpensive yet inefficient coal-, fuelwood-, paraffin-, or kerosene-powered stoves (Cawood 2003; Mqadi 2004).

The institutional inertia in South African government and society perpetuates the dominance of electric water heating systems. Prevailing practices in government, energy utilities, building industries, and other institutions all contribute to the tilt toward electric systems. For example, electricity utilities receive heavy government subsidies for their generating and distributing costs, including those associated with rural electrification programs. As a result, electricity tariffs are artificially depressed and alternative energy technologies are further marginalized. National and regional governments offer few incentives for people to adopt alternatives to electric water heaters, and in almost every instance, where manufactured water heaters are used, electric water heaters are the norm in all new and retrofitted homes.

Government support for SWH has generally been limited, but there are a few programs to stimulate markets for SWH and other small-scale renewable energy technologies. The city of Cape Town has committed to ensuring that 10% of households have SWH systems

[8] While electricity is relatively inexpensive, using an electric water heater still typically accounts for over 40% of a South African household's energy consumption.

by 2010, and it has initiated a number of activities to promote the technology. For example, it recently launched a CDM project that involves the installation of SWH coupled with energy efficiency enhancements in low-income areas. Other municipalities have experimented with installing SWH systems in city-owned apartment buildings.

B. Carbon abatement from solar water heating

The degree to which SWH systems abate carbon is a function of several factors, such as baseline emission factors for conventional water heating, average insolation rates, SWH system efficiency, and total system volume. Based on estimates of carbon abatement from typical residential SWH systems in each of six countries, Table 2 presents figures for carbon savings per system and per 100 liters, which enables equal comparisons between the countries.

Table 2: Carbon abatement from solar water heating in select countries

Country	Data source	Retail cost per liter	Number of liters in average system	Average cost of system	Tons CO2 abated /100L/ yr	Tons CO2 abated/ system/ yr
Barbados	Government	$6.00	300	$1,800	1.07	3.20
Brazil	Vitae Civilis; Econergy	$4.20	200	$840	0.46	0.92
China	Hua	$1.45	180	$261	0.45	0.81
China	Hua	$2.17	150	$326	0.45	0.68
India	MNES	$3.50	100	$350	1.50	1.50
Mexico	Quintanilla	$6.65	300	$1,995	0.59	1.77
Mexico	Davila	$5.66	265	$1,500	0.90	2.39
South Africa	SSN	$5.63	150	$844	0.96	1.44

In Barbados, government reports indicate that each of the roughly 32,000 systems saves around 4,000 kWh of oil-fired electricity generation per year, keeping a total of about 97,000 tCO_2 out of the atmosphere, or about 3.2 tCO_2 per system. Under certain baseline assumptions, SWH use in Brazil can account for nearly one tCO_2 emission abatement per system each year.[9] In China, where water is commonly heated via natural gas, LPG, or coal-generated electric systems, available data suggests that the average carbon abatement potential per system may be approximately 0.75 tCO_2. Given the high carbon intensity of India's electric grid, domestic SWH use yields substantial annual reduction of roughly 1.5 tCO_2 per 100 liter system. In Mexico, SWH systems can potentially reduce daily LPG use in the Mexico City metropolitan area by 21-35%, or

[9] In this study, the authors use a carbon emission factor of 0.604 kg of CO_2 per kWh for grid-based electricity in Brazil. This figure is taken from a submitted PDD for a CDM project in Southwestern Brazil, based on a formula that removes most hydroelectric generation to calculate the "operating margin" for the baseline, except a percentage used to supply electricity during peak periods (Econergy Brasil and Cia Açucareira Vale do Rosário 2003). A methodology excluding all hydropower and other renewables to calculate "operating margin" emissions is allowed for qualifying small-scale projects, as indicated in Appendix B of the Simplified Modalities and Procedures for Small-Scale CDM Project Activities.

around 1.77 tCO_2 per 300 liter system per year. And in South Africa, where coal-generated electricity is the main energy source for water heating, an estimate of carbon savings from SWH use is around 1.44 tCO_2 per 150 liter system year.

As illustrated by examples in Table 3, the ratio of emissions displacement to system cost can be more attractive for SWH than for some other renewable energy technologies. This ratio is generally more favorable for SWH than for solar photovoltaic applications and can be comparable to, or better than, that for wind and hydroelectric generation. The ratio of emissions displacement to system cost varies depending on local cost structures and renewable energy resource characteristics.

Table 3: Carbon abatement and system costs for select renewable energy applications

Technology application	System size kW (or equiv.)	Approx. system cost	Tons CO2 reduced/year	Tons CO2 reduced/$1,000
PV Water Pumping – India	1.4	$8,400	4.72	0.56
PV Home Lighting - Sri Lanka	0.04	$365	0.34	0.93
Hydro Power – Panama	9,000	$20,000,000	25,974	1.30
Solar Water Heating – Barbados	2	$1,800	3.20	1.78
Wind Power – Jamaica	20,700	$26,000,000	52,265	2.01
Hydro Power – Guatemala	43,000	$59,856,000	144,180	2.41
Wind Power – Chile	1,980	$2,576,000	7,200	2.80
Solar Water Heating – India	1.4	$350	1.50	4.29

Estimates based on published and unpublished data.

V. Potential SWH Market Boost from Carbon Finance

A. Potential CER revenue

All of the countries examined in this study have the potential to generate meaningful quantities of CER revenue from clean energy projects involving SWH technology. Using a conservative price of $5 per tCO_2 over a relatively short crediting period of ten years, projects in carbon intensive areas can potentially generate funds equal to over 10% of the system's original cost based on undiscounted CER revenue streams as illustrated by Table 4 below. In a project that involves thousands of new SWH systems, the monetary contribution can be substantial.

Table 4: Potential CER revenue from solar water heating

Ten-year period

Country	Data source	Average cost of system	CER revenue per system at $5/ton	CER value (% of system cost if CO2 at $5/ton)	CER revenue per system at $10/ton	CER value (% of system cost if CO2 at $10/ton)
Barbados	Government	$1,800	$160	9%	$320	18%
Brazil	Vitae Civilis; Econergy	$840	$46	5%	$92	11%
China	Hua	$261	$41	16%	$81	31%
China	Hua	$326	$34	10%	$68	21%
India	MNES	$350	$75	21%	$150	43%
Mexico	Quintanilla	$1,995	$89	4%	$177	9%
Mexico	Davila	$1,500	$119	8%	$239	16%
South Africa	SSN	$844	$72	9%	$144	17%

Fourteen-year period

Country	Data source	Average cost of system	CER revenue per system at $5/ton	CER value (% of system cost if CO2 at $5/ton)	CER revenue per system at $10/ton	CER value (% of system cost if CO2 at $10/ton)
Barbados	Government	$1,800	$224	13%	$448	25%
Brazil	Vitae Civilis; Econergy	$840	$64	8%	$129	15%
China	Hua	$261	$57	22%	$113	43%
China	Hua	$326	$47	15%	$95	29%
India	MNES	$350	$105	30%	$210	60%
Mexico	Quintanilla	$1,995	$124	6%	$248	12%
Mexico	Davila	$1,500	$167	11%	$334	22%
South Africa	SSN	$844	$101	12%	$202	24%

Twenty-one-year period

Country	Data source	Average cost of system	CER revenue per system at $5/ton	CER value (% of system cost if CO2 at $5/ton)	CER revenue per system at $10/ton	CER value (% of system cost if CO2 at $10/ton)
Barbados	Government	$1,800	$336	19%	$672	37%
Brazil	Vitae Civilis; Econergy	$840	$97	12%	$193	23%
China	Hua	$261	$85	33%	$170	65%
China	Hua	$326	$71	22%	$142	44%
India	MNES	$350	$158	45%	$315	90%
Mexico	Quintanilla	$1,995	$186	9%	$372	19%
Mexico	Davila	$1,500	$250	17%	$501	33%
South Africa	SSN	$844	$151	18%	$302	36%

Given system longevity of 15 to 20 years or more, most SWH project developers will probably opt for 14- or 21-year crediting periods. Based on 14-year crediting and a CER price of $10 per tCO_2, CER revenue would be substantial for SWH installations in all countries studied, having the potential to make an appreciable difference in project economics and a catalytic impact on market expansion. While Table 4 presents undiscounted figures, in the above example, CER revenue would still amount to 8% to 37% of initial equipment cost when applying a 7% annual discount rate. Toward the latter part of 2004, emission reduction transactions reported by Point Carbon and other outlets often reflected emission purchase commitments through 2012 or for a period of ten years. Once plans for mandatory GHG limitations beyond 2012 become more certain, carbon buyers may be willing to commit to CER purchases in advance over longer time horizons.

B. Potential benefits to SWH markets from carbon finance

As noted above, emission reduction revenues can be used to reduce the up-front costs of SWH technology; indeed, in some cases, revenue earned over a system's life span could defray over half or more of the expense to purchase SWH systems. In areas with high emissions baselines, CER revenue streams could reduce SWH system costs to consumers, increase the viability and profitability of SWH business activities, or both. In all the countries surveyed, up-front costs and system affordability represented significant barriers to broader household SWH markets. Even in Barbados, where average incomes are far above the regional average and where the government offers generous tax breaks to SWH buyers, it may be possible to use carbon finance to make systems more financially accessible.

Beyond reducing the up-front cost of SWH systems, carbon finance can help overcome other barriers to the development of SWH markets. Assuming project developers secure the interest of CER buyers, CDM activities can be structured to apply CER revenue for a wide variety of activities that effectively contribute to the removal of barriers. In this context, at least in theory, carbon revenue can fund SWH market development and promotion activities that help to overcome technology barriers, those of prevailing practice, or "other" barriers, such as limited information, managerial resources, organizational capacity, financial resources, capacity to absorb new technologies, and other institutional weaknesses. To obtain CDM approval, project participants would need to clearly define the intended barrier removal activities and establish a credible method for attributing specific system installations to the activities. They will also need to agree on a system for distributing the proceeds of CER sales. Still, SWH CDM projects could encompass a range of possible barrier-removal activities.

Almost everywhere, low-income buyers have difficulty financing SWH purchases due to high interest rates and very short loan repayment periods. This is often a function of a failure of financial systems – and particularly those that manage the systems – to understand the economic benefits of SWH applications. Carbon revenue could potentially help support efforts to educate financial officers about the long-term economic value of installed SWH technology. Carbon finance can also help open SWH markets to lower-income households through other innovative mechanisms, for example by assisting to secure underlying investments in fee-for-service operations.

Added investments to improve institutional capacity and support SWH market development by governments, the private sector, and NGOs can be very important to the long-term success of the SWH industry. In many geographic areas, the chain of dealers and installers is poorly developed. Thus, improved collaborative relationships between the parties involved in SWH markets can help establish and improve linkages from SWH import or local production to wide-scale diffusion.

Provided that project participants can establish and demonstrate a clear link between barrier removal activities and specific new SWH installations, the sale of CERs could potentially fund activities that strengthen the capacity of technology providers through training and other educational methods. For example, carbon finance could fund job training programs, which could have long-term benefits in the form of better-educated system design and installation professionals. Carbon finance could also help overcome technology barriers by supporting efforts to improve SWH equipment standards and testing regimes, which could be critical in areas where low quality products still proliferate. Improved and enforceable quality standards are critical in providing assurances to consumers that SWH systems will perform as promised; otherwise consumers will likely be permanently discouraged about the technology.

To address barriers that stem from the prevailing use of conventional water heaters, such as a lack of familiarity with SWH technology among prospective end-users and policy makers, and limited confidence in the technology, CER revenue could support awareness-raising activities that inform the public and decision-makers about SWH costs and benefits versus conventional systems. In both India and Mexico, one of the biggest barriers to the expansion of SWH markets reportedly is the popular conception that SWH systems are generally poor quality, even where systems meet existing quality standards. Demonstrations of high quality systems could reinforce claims that SWH can be reliable and provide substantial reductions in fuel cost. Presently, few resources are devoted to such public outreach efforts; if revenue from carbon reduction sales were used for such efforts, the effect on market acceptance could be substantial.

C. Challenges of scale and potential solutions

Even with streamlined procedures for small-scale projects, the transaction costs of CDM participation remain substantial. These include the cost of establishing baselines, developing and implementing monitoring and verification plans, and addressing and documenting other prerequisites for CDM participation. There are additional costs to identify buyers, negotiate an emissions reduction purchase agreement, pay an Operational Entity to validate the Project Designed Document, and pay CDM registration fees. These costs can easily add up to $100,000 for a small-scale project, and substantially more for projects that do not meet the definition of small-scale. Requirements of periodic verification by an Operational Entity further add to the cost of CDM participation.

The main buyers active in the carbon market often set minimum scale requirements below which projects will not be considered in light of the costs associated with preparing projects for the CDM, and the added cost of their own internal project selection and due diligence processes. The minimum project scale of many major buyers, including government agencies and private companies alike, is often 100,000 tCO_2e reduction per year. Even the CDCF, which focuses on small-scale projects, has a minimum scale requirement of 30,000 tCO_2e reduction per year. Considering that a residential SWH system will typically displace between approximately 1.0 to 3.5 tCO_2 per year, a project involving SWH applications exclusively may need to include 10,000 installations or more to meet minimum scale requirements, even for the CDCF.

To spread fixed costs more broadly across installations and to achieve minimum scale requirements for small-scale activities, bundling similar activities together can be an important strategy. For example, bundling SWH activities together with other renewable energy activities (e.g., small biomass, small hydro, etc.) can help open carbon reduction markets to SWH project developers. SWH industry participants and other sustainable energy stakeholders have started to explore options for project aggregation, and some have already developed proposals using project bundles to attract carbon finance. At the time of this report's publication, there were still no precedents where bundled projects involving SWH applications had completed validation for the CDM, but some projects were working their way through this process. As projects make it through the process of qualifying for carbon market participation and securing carbon finance, these precedents will help to demonstrate the viability of this approach.

VI. Conclusions

As a result of the above case studies and a broader examination of carbon finance, the authors draw the following conclusions:

- Solar water heating can be a cost-effective way to reduce GHG emissions - more so than photovoltaic applications and comparable to, or more so than, wind farms and hydroelectric facilities - especially where locally manufactured SWH equipment costs are low and carbon intensity of the baseline fuel is high.
- Water heating contributes substantially – in some cases 30% or more – to energy end use among households, so the potential for carbon abatement from SWH is considerable.
- Carbon intensity of baseline fuels for water heating varies, but it is generally substantial in most locations; carbon intensity is often greater in developing countries where energy conversion efficiencies are lower.
- Residential SWH markets can be quite diverse in developing countries, from urban markets for people who can afford cash payments up-front to low-income urban, peri-urban, and rural markets where system financing can enable hot water service for the first time.
- Solar water heating activities can generate a substantial amount of revenue from carbon market participation; in some locations, undiscounted revenue streams

can equal 25% to 50% or more of system costs at $10 per ton CO_2 and 14-year crediting.

- Transaction costs and minimum size requirements make it challenging for small-scale SWH activities to benefit from carbon finance, but project aggregation and precedents for SWH CDM activities will help make participation viable.
- The utilization of carbon finance to stimulate the delivery of hot water energy services in developing countries will contribute to meeting sustainable development goals.

Results of the case studies and an examination of carbon finance mechanisms lead to the identification of two overarching conclusions: 1) solar water heating can contribute substantially to carbon abatement while supporting the achievement of economic development goals, and 2) carbon finance can help overcome barriers to the broader adoption of solar water heaters.

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