Carbon Finance and Solar Water Heating Technology

Exploring Possible Synergies Through Five Case Studies

Master of Arts in Law and Diplomacy Thesis

Submitted by Samuel Milton

May 2004

Under the advisement of Professor William Moomaw

http://fletcher.tufts.edu

The Fletcher School

Carbon finance and solar water heating technology: exploring possible synergies through five case studies

Abstract

This paper explores the potential of carbon finance to boost markets for solar water heating (SWH) technology in developing countries. The promise of greater adoption of SWH systems into a global energy paradigm is important for sustainable development efforts, since SWH systems can yield multiple local and global environmental, economic, and public health benefits. Carbon finance, in particular, is an important vehicle for sustainable development due to its ability to harness market forces for the greater good.

In this paper, after a brief introduction of the issues, the second section offers an outline of the political, economic and environmental context in which carbon finance has evolved to become an important tool for the global effort to reduce emissions of anthropogenic greenhouse gases. This paper then examines specific carbon trading mechanisms that have developed over years of negotiation and trial and error, such as the Clean Development Mechanism (CDM) and the Community Development Carbon Fund (CDCF), and it provides an overview of the myriad components of these mechanisms that are especially critical for their meaningful contribution to sustainable development. It concludes the third section with a summary of the current market for carbon-based commodities.

The fourth section offers a survey of SWH technology and describes some of the technology's attributes that make it a suitable component of sustainable development efforts. This section also introduces many of the barriers that have traditionally prevented SWH from gaining a foothold in the residential and commercial energy sectors. The fifth section then explores how the CDM and CDCF could affect SWH markets. It does this first through a specific examination of these mechanisms' operational modalities and then attempts to find possible linkages where SWH markets can take advantage of carbon markets.

Through the lens of five case studies of countries that have active SWH markets – Barbados, China, India, Mexico, and South Africa – the sixth section assesses the state of the SWH market in those countries and seeks to find more precise possible synergistic relationships between those markets and carbon finance. It explores many aspects of the these countries' demand for hot water, prevailing market conditions for conventional fuels and SWH technology, barriers to greater SWH adoption, and current initiatives to strengthen the position of SWH in the domestic marketplace. This section concludes by offering some insight into the potential for carbon finance to influence SWH markets. Finally, the last section offers some closing remarks and considerations for future activities to stimulate further synergies between carbon finance and SWH markets.

Table of contents

Abbreviations used

CDCF	Community Development Carbon Fund
CDF	Clean Development Fund
CDM	Clean Development Mechanism
Ce	carbon equivalent
CEF	carbon emission factors
CER	Certified Emissions Reduction
CFC	chlorofluorocarbon
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COP	Conference of Parties
EB	CDM Executive Board
ERPA	Emissions Reductions Purchase Agreement
ET	Emissions Trading
GEF	Global Environment Facility
GHG	greenhouse gas
IET	International Emissions Trading
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
KP	Kyoto Protocol
LDC	Least Developed Country
LPG	liquefied petroleum gas
MNES	Ministry of Non-Conventional Energy Sources (India)

NGO	non-governmental organization
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

Climate change is a multifaceted phenomenon, the outcome of myriad climatic, environmental, economic, political, historical, institutional, social and technological factors. There is overwhelming consensus in the scientific community that climate change will dramatically alter the global climactic system, sending reverberations throughout virtually every corner of the earth. For many of the Earth's six billion people, climate change is already a matter that they confront daily. Unfortunately, a perverse aspect of global climate change is that its effects will be most profoundly felt by those who are least responsible and least able to adapt – the world's poorest. Indeed, not only will lesser-developed countries be unable to pay for many adaptive measures needed to cope with the changing global environment, but these countries are also often located in geographic areas that will be most affected by the environmental, health, and social ramifications of climate change. In light of the profound changes that global warming will have on every nation, it is of utmost importance for the international community to reduce the factors that contribute to it.

The world's foremost climate scientists have concluded that anthropogenic climate change is primarily due to the emission of greenhouse gases (GHGs) that are generated from the combustion of fossil fuels by the world's many power plants, automobiles and other activities related to the energy sector. Thus, finding ways to pursue economic development that do not require massive use of fossil fuels is one of the most important steps in meeting the objective of the United Nations Framework Convention on Climate Change (UNFCCC). In order to reverse the planet's perilous path toward severe and irreversible climactic perturbations and its resulting long-term consequences, the world's various actors must undertake a wide range of activities to match the equally numerous components of climate change.

A critical measure that the international community can take to reducing current and future GHGs is to help developing countries tackle their own growing energy needs with alternatives to fossil fuels. Alternatives such as renewable energy can dramatically curtail future increases in GHG emissions, while also helping to meet the immediate consumption needs of the developing world. The creation of regional, national, and international GHG emissions trading markets can play a strong role in catalyzing renewable energy initiatives in industrialized and developing countries alike.

With over forty-five existing, planned, or proposed markets for the exchange of GHG emissions allowances and reductions credits, carbon finance has emerged as one of the preeminent tools available to funding clean energy and carbon reduction projects (Hasselknippe 2003; Point Carbon 2004). Many developed countries and corporations have already traded millions of tons of carbon, resulting in significant global GHG emissions reductions and cost savings for the parties involved. Developing countries are using carbon trading to create opportunities for private entities to channel capital to domestic clean energy initiatives, but additional opportunities abound.

One of the most prominent carbon finance programs to attract the attention of many, if not all, of the carbon trading institutions is the Clean Development Mechanism (CDM), a system that emerged from negotiations on the UNFCCC. Barring the complete collapse of the Kyoto Protocol (KP) and its progeny, the CDM will remain a focal point of the global community's efforts to positively influence carbon reduction and sustainable development. Other vehicles structured to leverage carbon finance for sustainable development and climate protection include: The World Bank's Prototype Carbon Fund (PCF) and Community Development Carbon Fund (CDCF) and the Dutch Government's CERUPT and ERUPT programs, all of which are designed to operate under the KP's rules; and the Carbon Trust of Oregon and the Chicago Climate Exchange, which are designed to operate outside the Protocol's purview, among others.

Solar water heating (SWH) technology is one of the simplest and oldest ways to harness renewable energy, and it can also contribute significantly to 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 m^2 of total installed capacity in 2002. Nearly one third of homes in Barbados are equipped with SWH systems (Jensen 2000), and in India they are the most commercialized renewable energy technology (ESTIF 2003). Hot water is increasingly seen as a fundamental aspect of modern hygienic and healthy life in contemporary societies, and demand for it will undoubtedly grow (Jensen 2000). However, there are still substantial barriers to additional SWH technology diffusion in developing countries. Among the most pervasive are related to high cost, and policy, promotion or technology failures. For example, SWH markets tend to suffer where technology costs are high and where electricity (or whatever the conventional water heating fuel source is) costs are low. All too often, the policy measures needed to help meet this growing demand, such as public awareness campaigns, equipment quality standards, and initiatives to increase private sector capacity, are inadequate (GEF 1999).

Carbon finance can be an important vehicle to providing the boost necessary to meet the SWH technology needs in many developing countries. When the politics and idiosyncrasies associated with the CDM are resolved, it could be particularly instrumental in catalyzing markets for SWH technology. In this paper, I will attempt to demonstrate how carbon finance and SWH technology can work in tandem to slow the impact of global climate change and help achieve sustainable development.

II. Climate change and the need for innovative solutions

As a direct result of man's rapid industrialization, the Earth's average temperature has increased by 0.6 ± 0.2°C over the 20th century, a change so abrupt and extreme as to defy any naturally occurring cause. Climate scientists predict an additional increase by 1.4 to 5.8°C over the next 100 years. With each ounce of fossil fuel that we burn, heat trapping carbon dioxide and countless other chemicals are released into the atmosphere. After a century and a half of burning these fuels, we have increased the pre-industrial concentrations of carbon dioxide in the atmosphere by 31%. Atmospheric concentrations of methane, a particularly potent GHG, have increased by 2.4 times. Levels of nitrous oxide, also a significant GHG, have increased by 14%. The concentration of other heat-trapping outputs of industrialization in the atmosphere such as chlorofluorocarbons (CFCs), and its various replacements, such as hydrochlorofluorocarbon and perfluoromethane, and ozone has also dramatically increased. Other human activities also emit GHGs that alter the atmosphere. Deforestation, fires, and destructive land use practices emit carbon dioxide, methane, and nitrous oxide, thereby increasing the Earth's reflectivity of sunlight and compounding the effect of global warming. Significant quantities of methane are also emitted from waste sources, including sewage, landfills, and animal feedlots, as well as from artificial lakes made by damming rivers for electricity and recreation (IPCC 2001).

Most climate scientists concur that global warming will have many ramifications beyond that of an increase in average global temperature. Among some possible outcomes are: sea level rise due to glacial retreat, melting ice caps and thinning polar sea ice; increased intensity and frequency of dramatic climactic events such as hurricanes, cyclones, rain storms, extended heat waves, and drought; a reversal of ocean currents, such as the gulf stream; and changes in the habitat of all forms of life, including birds, fish, plants, trees, insects, and even dangerous microbes, to name a few (IPCC 2001).

Sustainable development challenges in the face of global climate change

While the exact figures are hotly debated, few scientists dispute the fact that the world's industrialized nations are responsible for emitting the majority of the atmospheric anthropogenic climate altering gases. Sadly, the world's developing world population will be most likely the hardest hit by global climate change. An international committee set up by the UN to asses the science of climate change, the Intergovernmental Panel on Climate Change (IPCC), has predicted unsettling consequences for countries in the developing world. For example, most tropical and sub-tropical regions, areas of the world where the vast majority of the poor live, will likely suffer a general decrease in crop yield. The IPCC also predicts decreased water availability for populations in water-scarce regions, particularly in the sub-tropics, and an increase in heat stress mortality (IPCC 2001).

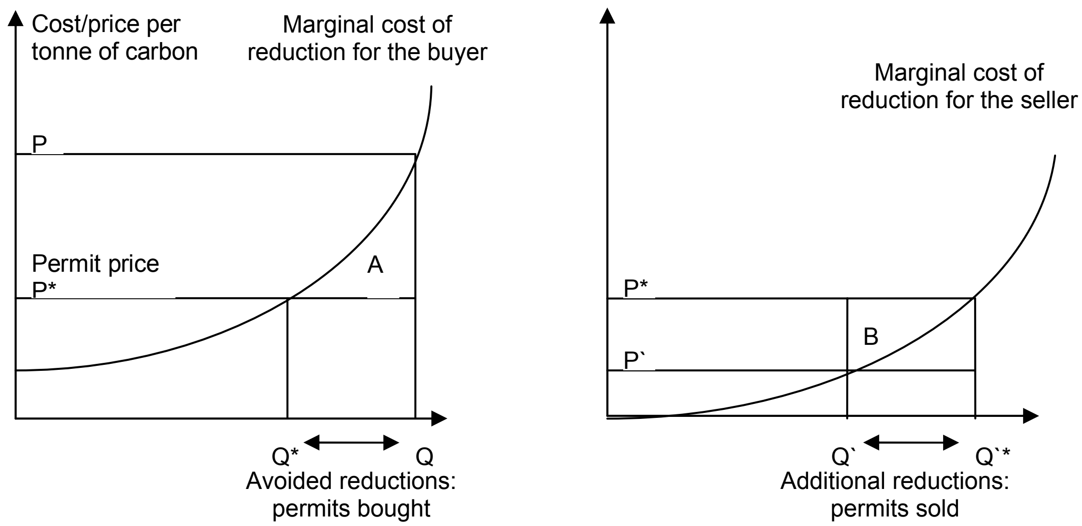
Tens of millions of people currently living in low-lying areas around the world are at a significant risk of experiencing flooding, from both an increase in heavy precipitation and rising sea-levels. Island nations and residents of heavily populated coastal cities such as Dhaka, Lagos, Jakarta, Abidjan, Rio de Janeiro, Havana, and Mumbai (to name just a few) risk vast loss of land area, resulting in massive population displacement. Some Pacific island nations are already under water, and their citizens evacuated. Many others are bracing themselves for the eventual reality of bring forced to flee their homes, with little hope of returning (Knox 2002). People living in other sub-tropical areas will likely see an increase in the incidence of exposure to both vector-borne (e.g., malaria) and water-borne (e.g., cholera) diseases (IPCC 2001). In the developing world alone, over the next several hundred years, the IPCC estimates 2.3 million people will be forced to leave their homes, 114 deaths per 1,000 will be attributed to climate change, over 150 cubic kilometers of water will be lost, and agricultural failure will result in an average loss of 0.28% of national GNP (Fankhauser 1995). Developing countries are, on average, twice as vulnerable as industrialized countries, according to a UN Vulnerability Index. Small island countries are actually three times as vulnerable (Anonymous 1990).

III. Carbon finance and credit trading

The notion of using financial and market-based mechanisms to control pollutants and emissions has existed for decades, though mostly in the theoretical realm. Emissions trading theory is founded on the principle that if pollutants – or the potential of pollutants – were given a negative monetary value, then not only would society be able to establish the social costs of pollution, but those creating it would be able to rationalize potentially costly reductions in pollution emissions.

Over the past several decades, policy makers have had some success experimenting with various systems of pollution permit trading to manage domestic emissions problems (McKibbin 1998). In particular, advocates of emissions trading point to the United States's sulfur dioxide trading scheme as an excellent tool for firms to achieve cost-savings, while complying with national SO_2 emission reduction requirements (IEA 2001; Pronove 2002; EPA 2003). Some scientists, however, suggest that unrelated factors may have had a more significant contribution to emissions reductions during the trading period (Ackerman and Moomaw 1997). Still, due to sound economic theory and reasonable success in practice, emissions permit trading is permanently enshrined in environmental protection circles as a viable means to reduce some of the negative environmental externalities of industrial activity.

Box 1: The Economic Logic of Tradable Permits



An emission source — on the left-hand side — needs to achieve Q reductions to comply with its emission objective. If it undertakes reductions domestically, it will incur a marginal cost P. But with a price of tradable permits P which is lower than P, it will only reduce its emissions to that level and will buy permits to make up the difference between Q and Q*. Area A represents the cost savings achieved through buying permits. The same logic applies for a source with marginal cost below the market price — on the right-hand side — with an objective Q' and a marginal cost P' that is lower than the market price P*. The source will reduce emissions up to Q'* and sell the surplus permits at a profit. Its net benefit from the trade is represented by area B. All sources should therefore aim for a reduction strategy that results in a marginal cost equal to the permit price.*

IEA (2001). International Emission Trading: From Concept to Reality. Paris, International Energy Agency.

During negotiations to develop a protocol for the UNFCCC, American delegates promoted an International Emissions Trading (IET) scheme as a cost-efficient way to address growing greenhouse gas emissions. The American SO_2 trading system had several characteristics that contributed to its success, such as the availability of continuous real-time monitoring of emission sources and a central regulatory agency. However, even though these elements will not likely exist in a global GHG context, emissions trading has since become the linchpin of international efforts to reduce these gases (IEA 2001). Indeed, many rounds of the Conference of Parties to the UNFCCC since Kyoto have revolved around fine-tuning the proposed trading-related flexibility mechanisms (ENB 2000; ENB 2002).

A big challenge trading emissions under the Kyoto Protocol is to extrapolate from national trading systems a viable form of international cooperation. In fact, unless all Annex I countries negotiate for the same incentives to reduce their emissions, economic efficiency in GHG abatement will be difficult to achieve (IEA 2001). Moreover, it is necessary that developing countries participate in IET to maximize these efficiencies. They can do this by substantially reducing the global marginal cost of meeting transnational GHG emissions reductions targets, though the role of developing countries as equal partners in trading programs remains uncertain. Still, it is important for developing countries to participate in emissions trading for several reasons: they have the advantage of relatively low energy prices and labor costs, and in countries that have relatively brisk economic growth such as China and Brazil, the potential for improvements in energy efficiency – and sales of emissions permits – is immense (McKibbin 1998; IEA 2001).

Several groups have carried out modeling scenarios to forecast the impact of emissions trading on the global economy. The results suggest what economic theory predicts: under competitive circumstances, global gains are possible when countries trade. While most countries that trade would experience a reduction in national income, except those whose actual emissions are less than their Kyoto commitments, the decrease in income is less that if global emissions were reduced by the same amount in the absence of trading. However, it must be noted that most of the models that have been run thus far are based only upon OECD countries and their specific circumstances. To date, very few of them consider the CDM or attempt to gauge the impact of global emissions trading on developing countries. In addition, those that do incorporate the CDM often use assumptions bearing little resemblance to the realities that countries participating in the CDM are likely to face (Interlaboratory Working Group 2000; IEA 2001).

Carbon trading mechanisms

During many sessions of the UNFCCC, the Convention's fate seemed to hinge on the successful incorporation of a mechanism that would facilitate emissions trading(ENB 1998; ENB 2000). Instituting an IET scheme is perhaps the international community's most politically viable proposal to address climate change. The most effective trading scheme would be one that involves a tool, like the CDM, that can. The CDM, because it systematically addresses both the desire of the North to reduce GHG as well as the South's need to grow, has traditionally been the focal point for a trading scheme that would target developing countries. However, many observers are beginning to believe that the CDM, as an institution, will never come about due to a failure of negotiations (Jaura 2002; Doyle 2003). Thus, in the absence of a binding Kyoto Protocol that mandates participation in an IET system, a host of voluntary and mandatory systems have evolved to fill the role of the CDM and offer opportunities for clean energy development in resource-poor countries (Hasselknippe 2003).

The idea of creating a funding mechanism that could both assist developing nations to achieve sustainable development and reduce the global carbon burden evolved from an early recognition of two important points: 1) that GHG emissions to date are primarily the result of industrialization, and 2) that the priorities of developing countries should tend naturally towards greater development. In fact, as early as the 1988 Conference on Changing Atmosphere in Toronto, there was talk of a fund to facilitate the transition of poor countries' current development path, from one modeled after industrialized nations to a new, clean paradigm that did not rely on fossil fuels (Agarwal et al. 1999)

As the climate debate intensified over the following years, countries negotiated the details of such a fund. Most parties agreed that a mechanism to facilitate technology transfer and clean development should be an integral part of a climate change treaty, but the consensus ended there. A primary point of contention between the industrialized and developing countries was on whether the Global Environment Facility (GEF) – managed jointly by the World Bank, UNDP, and UNEP – should be designated as the financial mechanism for any climate convention (Srivastava and Soni 1998). The Southern delegates' primary contention with the GEF was based on fundamental inequalities in the international system between the North and South. In other words, they disputed the Northern countries' traditional monopoly over the decision-making process at the World Bank and other Bretton Woods Institutions. However, after the GEF amended its constitution to require greater participation by developing countries, the UNFCCC delegates compromised and agreed that the GEF would be the interim funding mechanism for climate-related projects.

During the seventh session of the Ad-Hoc Group on the Berlin Mandate in 1997, Brazil introduced a new financing mechanism for climate projects that would not have the institutional constraints and political baggage of the GEF. Brazil's proposed Clean Development Fund (CDF) would have been financed by non-compliance fees from Annex I countries that exceeded their assigned amounts of greenhouse gas emissions in a given budget period. It was based on the "polluter pays" principle, where Parties in non-compliance "contribute" to the Fund by paying a fine of $10 per ton of carbon that it emitted over its allocation. The CDF lived on until a few months later, when it became a casualty in a "grand bargain" between the U.S. and the rest of the world (Agarwal, Narain et al. 1999).

The Clean Development Mechanism

In 1997, Parties to the Convention (COP) gathered in Kyoto to discuss a protocol for implementing the outlined commitments. The document, henceforth known as the Kyoto Protocol, was a landmark work for many reasons, but particularly in that it codified several unique flexibility mechanisms aimed at engendering creative emissions reduction projects. These mechanisms are: Emissions Trading (ET), Joint Implementation (JI), and the CDM, which grew directly out of Brazil's original proposal for the CDF. ET, JI, and CDM all evolved from an earlier initiative, Activities Implemented Jointly (AIJ), that was established at COP-1 to provide flexibility to the Annex I Parties, i.e., developed countries, in meeting their commitments through cooperative mitigation activities amongst themselves and with non-Annex I Parties, i.e., developing countries. The CDM is a specific mechanism designed to help countries listed in Annex I reduce the cost of meeting their emissions targets by taking advantage of less expensive opportunities in other countries (UNFCCC 1997). Although it was in essence a watered down CDF, it was immediately hailed as one of the highlights of the Conference and a savior for both Annex I countries looking for cheap ways to earn reduction credits and for non-Annex I Parties looking for investors in their clean development projects.

Potential CDM projects must meet several requirements to create tradable Certified Emissions Reductions (CERs). Two of the most important clauses are the "additionality" and "sustainable development" clauses. First, the additionality clause states that a CDM project must lead to real and measurable reductions in the host country's total greenhouse gas emissions, which can be achieved either by real emissions reductions at the source, or through absorption – or sequestration – of greenhouse gases. The clause also stipulates that project developers must prove how GHG emissions will be reduced below the levels anticipated in the project's absence. Also, CDM project developers must demonstrate that their project would have met at least one of the four following barrier categories: investment, technology, prevailing practice, and "other" (UNFCCC 2003). This clause is intended to help guarantee that CDM projects legitimately contribute to efforts to stabilize global greenhouse gas concentrations.

An important clause for Southern governments is that all CDM projects must contribute to sustainable development goals in the host country and must not generate any negative environmental externalities (Humphreys et al. 1998; Sokona et al. 1998; Agarwal 2000). To this end, host nations are required to consult with project stakeholders before submitting the project to the Executive Board (EB) for approval. Also, the host country may reserve the right to request an environmental impact assessment for the project and exercise veto power over any project that does not meet a sustainable development agenda (UNFCCC 2002).

The 2001 Marrakesh Accords, signed during COP-7, underscored four additional points that the South had also been demanding, namely: 1) recognition that the CDM should lead to the transfer of environmentally safe technologies, 2) that public funding for CDM projects from Parties in Annex I is not to result in the diversion of official development assistance and is to be separate from and not counted towards the financial obligations of Parties included in Annex I, 3) that the CDM should promote equitable geographic distribution of project activities at regional and sub-regional levels, and 4) that CERs may not be generated from nuclear power projects. Marrakesh also elaborated on the question of carbon sequestration, notably those related to land use, land-use change, and forestry projects (UNFCCC 2002).

The Marrakesh Accords also finalized some remaining details of the CDM's governing body. It created the CDM EB, which is the supervisory body of the CDM and is ultimately accountable to the Conference of the Parties; the EB also oversees the negotiations on climate change until the Kyoto Protocol enters into force. The first ten voting members and ten alternate members of the CDM EB were elected in Marrakesh during COP-7. As stated in the Accords, the EB must consist of ten voting members, comprising one member from each of the five UN regional groups, two additional members each from Annex I and non-Annex I Parties, and one representative of the Association of Small Island States, as well as 10 non-voting alternates based in the composition formula (UNFCCC 2002; UNFCCC 2002).

Meeting the additionality requirement

Prior to receiving CDM finance, developers must submit a Project Design Document (PDD), which contains information about the project's boundary, baseline, expected emissions reductions, and monitoring plan. A major component of meeting the CDM's additionality requirement is the establishment of a methodology for estimating baseline scenarios. The baseline is an estimated measurement of emissions that would have occurred in the absence of the proposed project activity; this is subsequently used to estimate the total emissions reductions from the project. The total value of CERs is a function, therefore, of the baseline measurement and thus has tremendous impact on the project's viability. Consequently, the most important methodological issue with CDM projects is establishing its baseline, and the choosing of the appropriate baseline is extremely relevant since it affects the extent of emissions credits that a project will generate (Spalding-Fecher et al. 2002).

For small-scale (SSC) CDM projects, developers may standardize baselines to minimize the high transaction costs associated with sometimes crippling low economies of scale[1] (Michaelowa et al. 2003; Pembina Institute 2003; World Bank 2003). To that end, various actors have identified baseline selection techniques specifically for use with SSC projects. One baseline-related decision that developers of SSC projects must make concerns the use of project-specific baselines versus multiple-project or hybrid baselines (Spalding-Fecher, Thorne et al. 2002). The choice between project-specific and multi-project approaches involves a trade-off between transparency, error, and transactions costs, and consequently requires a compromise between environmental stringency and investor incentive (MNES 2004).

Project-specific baselines examine the emissions at a single project site and do not extrapolate from other projects or circumstances to determine a baseline measurement. The advantage of project-specific baselines is that they capture more accurately the situation that would exist in the absence of the CDM project, and hence, the real emissions reductions resulting from the project (MNES 2004). Multi-project baselines are aggregated baselines associated with various activities, often at a sectoral or sub-sectoral level. Proponents of multi-sectoral methodologies argue that their use drastically reduces transaction costs compared to the high costs of developing project-specific baselines (Lazarus et al. 2000; Michaelowa, Stronzik et al. 2003). Multi-project baselines can include benchmarks, activity indicators or intensity standards (Spalding-Fecher, Thorne et al. 2002).

---

1 Some estimates suggests that the total costs of monitoring, verification and registration package alone could be 5-10% of the total project budget, and up to 20% of the cost of pilot projects Spalding-Fecher, Randall, Ed. (2002). The CDM guidebook: A resource for clean development mechanism project developers in Southern Africa. Cape Town, Energy and Development Research Center (EDRC).

, IPMVP (2003). Concepts and Options for Determining Energy Savings. Washington, DC, International Performance Measurement and Verification Protocol.

Independent of the decision to aggregate multiple projects or not, project developers often utilize methodologies that have been previously accepted by the CDM EB. For most CDM projects, there are three acceptable methodologies that are used to measure the baseline of a CDM project: status quo emissions, market conditions, or best available technology (Pembina Institute 2003). The status quo emissions approach is the most straightforward and easiest to use, as one extrapolates from current trends to determine future emissions. An important drawback to this methodology is that it fails to take into account technological developments that lead to more efficient processes, as well as regulatory revisions and significant market restructuring that may affect the intensity of future emissions.

To account for uncertainties, one can apply a methodology that considers market conditions. This approach assumes that the technology normally used under current market conditions is the baseline, but it takes into account market barriers, such as lack of financing and product distribution channels, when selecting the baseline. This is particularly important in energy efficiency projects where these barriers discourage adoption of otherwise cost-effective, high efficiency technologies, and the project helps to remove these barriers. A third popular methodology considers best available technology. This approach is most useful in rapidly changing markets where historic emissions are not relevant. In this case, the "best commercially available technology" is used as the baseline, and the average emissions of similar project activities undertaken in the previous five years (in similar social, economic, environmental, and technological circumstances), is included (Pembina Institute 2003).

In the event that none of the above methodologies are applicable on their own, a combination may be used, or even none at all (VROM 2001; Pembina Institute 2003). To further reduce transaction costs, project developers might consider bundling several similar projects into one, e.g. bundling 15 electricity projects of 1 MW each, hoping to take advantage of fast-track procedures that permit larger projects (MNES 2004).

Baselines can either be fixed for the lifetime of the project or revised during the project operation. Developers must choose between a fixed ten-year crediting period or renewable seven-year renewable crediting periods, which may be renewed a maximum of two times. Because fixed baselines do not change over their ten-year crediting period, they tend to be more predictable and require less administrative, monitoring, reporting, and other transaction costs than dynamic baselines. However, renewable, or dynamic baselines, have the benefit of ensuring greater accuracy in measuring the environmental additionality of a project. Dynamic baselines also offer the potential of earning CER revenue for up to 21 years (Spalding-Fecher 2002; Pembina Institute 2003; UNFCCC 2003).

Meeting the sustainable development requirement

The CDM's sustainable development requirement is arguably more difficult to quantify than the additionality requirement. Indeed, the process of determining if a project has met suitable sustainable development requirements is entirely left up to the host country and can vary widely depending on the country's specific development agenda. Because of the high degree of subjectivity that surrounds the requirement, many observers of the CDM suggest that potential host countries begin to identify social monitoring guidelines and criteria to help ensure that projects generate a high social return.

The need to develop guidelines for determining the social development aspects of CDM projects is particularly urgent, some argue, given that there could be immense pressure on developing countries to approve as many CDM projects as possible, in order to serve as a conduit for CERs to developed countries (Austin and Faeth 1999). With strong sustainable development criteria, climate change projects have a greater potential of being meaningful and gaining local relevance.

Potential CDM projects should be pre-screened to determine if they would meet or enhance the domestic, national and local agenda for sustainable development. To that end, projects should meet some of the following requirements. They should be compatible with and supportive of national and local development priorities, contribute to social development and minimize adverse social and cultural impacts, fit in with the national climate change agenda, encourage local institutional linkages, ensure transparency and participation by project recipients. In addition, projects should aim to transfer technology and build local capacity, and bring about measurable sustainable development benefits to the recipients (Matibe 1999; Millock 2002).

In practice, host countries would likely assess the sustainable development benefits of CDM projects by analyzing several social issues, such as poverty alleviation, meeting of human basic needs and access to resources, job creation and income generation, health, capacity building and training, acquisition of skills, remote and rural areas electrification, cultural adaptability of climate change projects, gender equity and even comfort and safety. Other development indicators must also be considered, such as air and water quality, enhanced soil preservation, flood protection initiatives, biodiversity protection, and solid waste minimization programs (Matibe 1999).

Table 1: Examples of sustainability indicators

Sustainable development issues	***Indicators***
Jobs	Types of employment created Number of persons employed Duration employed Earnings
Health and safety	Incidences of respiratory infections e.g. asthma, bronchitis Incidences of eye infections related to indoor air pollution Damage from fires and paraffin poisoning
Capacity building in skill	Types of skills learned Duration of training Applicability of skills Employability of trained workers
Income generation	Enterprises arising due to project implementation
Savings	Reduced energy expenditure
Comfort levels	Perception of comfort
Cultural impacts	Sensitivity of the project and all its processes to the local culture
Equity	Sex, gender, age and generational issues. Is the project sensitive to the needs of all age groups, different genders, etc.?
Education	Impact on local education and educational opportunities created
Soil preservation	Fertility of soil
Perceptions of social status	Feelings about the differences between conventional and clean energy technologies
Local environmental protection	Quality of local water resources Incidences of respiratory infections
Biodiversity	Incidence of habitat loss
Deforestation	Incidence of fuel gathering and tree felling Availability and prices of wood-based fuels such as charcoal and fuelwood

Table adapted from: Matibe, Khorommbi (1999). Social monitoring guidelines for flexible mechanism projects under the United Nations Framework Convention on Climate Change in South Africa. Cape Town, Energy and Development Research Centre.

The Community Development Carbon Fund

The World Bank developed the Community Development Carbon Fund to complement the CDM. It is an instrument to provide communities in developing countries, and in particular Least Developed Countries (LDCs), with access to investments in renewable energy and clean technology via the carbon markets. To that end, the CDCF purchases CERs from projects in LDCs that meet the regulatory requirements of the CDM while reducing the high transaction costs that SSC CDM projects often face. All while striving to maintain the integrity of environmental, social and economic benefits of clean technology for the local communities (World Bank 2003).

The CDCF is a product of the Prototype Carbon Fund, the Bank's initial and continuing efforts to stimulate the worldwide market for carbon reduction credits, which it inaugurated in 2000. From its experience with the PCF and other endeavors, the Bank has identified important weaknesses in the existing carbon market framework. For example, the Bank found that the private sector generally avoids LDCs and economies in transition as places to acquire CERs unless there are additional incentives to attract them. Second, few developing countries can deliver CERs in large quantities, and the vast majority of these countries do not have large and rapidly growing sectors that would typically be attractive to the private sector. Furthermore, high transaction costs and the high risks associated with relying on carbon finance to fund small-scale projects means that most of the smaller and poorer countries are unlikely to benefit from the catalytic investment effect of carbon finance (Michaelowa, Stronzik et al. 2003; World Bank 2003).[2]

To address the lack of participation by developing countries in the carbon market, the World Bank launched the CDCF in 2002 at the World Summit on Sustainable Development in Johannesburg, South Africa. While the Fund is still relatively new, the CDCF is already considered by many to be one of the best tools yet to greatly increase the participation of developing countries in the carbon

2 Many early observers of the debate on the role that international carbon trading would play in sustainable development predicted many of these outcomes. For additional insight into these limitations and more, see Anil Agarwal (2000). Making the Kyoto Protocol work: Ecological and economic effectiveness, and equity in the climate regime. New Delhi, Centre for Science and Environment (CSE); Duncan Austin and Paul Faeth (1999). How much sustainable development can we expect from the Clean Development Mechanism? Climate Notes November.; Youba Sokona, Stephen Humphreys, et al. (1997). The Clean Development Mechanism: What Prospects for Africa? Dakar, Energy Programme, ENDA- TM; and Njeri Wamukonya (2001). Meeting Africa's Energy Demand: Can CDM Offer any Relief? IMPACT.

market (TERI 2002; Sokona 2004; Varughese 2004). Through the CDCF, the World Bank attempts to improve linkages between private sector participants and community development projects. Partly by working with local intermediaries, such as financial institutions, micro-credit institutions, cooperatives and non governmental organizations, and also by applying streamlined project procedures compatible with SSC Kyoto projects, the CDCF lowers risks and transaction costs associated with these projects (World Bank 2003).

The CDCF offers features that other funds and buyers of CERs do not have. For example, it offers some aspect of regulatory certainty that other funds cannot. This is because Designated Operational Entities – the various parties involved in the CDM transaction – can validate projects and register their emissions reductions through the CDCF without further review by the CDM Methodology Panel and the EB. Users of the CDCF can also take advantage of the Fund's current operational status and trade immediately. This will enable these parties to maximize their trades by 2012, when the first trading period ends. Also, the prices at which CERs will be traded through the CDCF will likely be higher, more stable, and more consistent with their actual costs than those so far recorded in other CER markets (World Bank 2003). The CDCF also serves to allay some of the uncertainty associated with the fate of the CDM, as participants can take solace that CERs purchased via the CDCF are more likely to be recognized by future greenhouse gas emissions regulatory regimes, regardless of whether the CDM is part of an internationally binding treaty.

The following principles that apply to the CDCF: the purchase of emissions reductions will be consistent with the requirements of the UNFCCC and the Kyoto Protocol; there will be equitable distribution between both the participants and the recipients of the funds of the benefits resulting from the projects; and the Bank will disseminate the knowledge gained as a result of the Fund development. In addition to these general principles, the CDCF pledges to adhere to the following five points:

(i) The CDCF's principal activity will be to purchase verified emissions reductions and CERs on behalf of its participants through the entry into Emissions Reductions Purchase Agreements (ERPAs);.

(ii) The CDCF will actively seek to reach countries and communities that are neither presently benefiting from development through carbon finance nor are likely to benefit greatly from it in the future. To this end, the Fund management will use its best endeavors to place a minimum of 25% of the Fund into eligible projects located in LDCs and other developing countries.

(iii) The CDCF will facilitate projects which include, as a measurable output, the provision of goods and services that under normal circumstances would lead to improvements in the social welfare of the communities involved in the projects. Where there is no identifiable community integral to the project, a beneficiary community will be identified. These project outputs will be certified by entities independent from the Fund.

(iv) The CDCF will purchase emissions reductions from projects that meet the definition of "Small-Scale CDM Project activities" included in decision UNFCCC 17/CP.7 and with the simplified modalities and procedures for small-scale CDM Project activities adopted by the eighth session of the COP (e.g. renewable energy projects with a maximum output capacity of 15 megawatts). Experience with the PCF shows that the great majority of potential projects in least developed countries and the poorer areas of developing countries fall under the small-scale project definition.

(v) In the short term, the CDCF will be expected to have a higher unit price per ton of emissions reductions than applicable for those arising from larger CDM projects in the larger non-Annex 1 Countries. Price differentials may be reduced in the medium term as demand exceeds supply in the core CDM market focused on larger projects in larger and middle income developing countries (World Bank 2003).

Current market conditions

The expectation of the Kyoto Protocol's eventual entry into force has traditionally been a primary driver of carbon markets. However, the market for carbon emissions reduction credits has so far been quite small, though it is rapidly growing. As of late 2002, only about 200 million tons of carbon dioxide equivalent had been traded since the Kyoto Protocol's inception in 1996 (World Bank 2003). Historically, the largest buyer of carbon reduction credits has been the Dutch government, via their ERUPT and CERUPT programs. While the market is still dominated by a small handful of players, other public and private entities are entering the market, especially as regulatory regimes such as the European Union's emissions trading system gain strength and popularity. International prices have ranged from a few cents a ton to about \$10 per ton of CO_2 equivalent (CO_2e) (US dollars used throughout, unless noted otherwise)(Lecocq and Capoor 2002). These prices are only a fraction of the real cost of CO_2 abatement in the more energy-efficient Annex I countries, which range from about \$15 to well over \$100 a ton of CO_2e, though large scale energy efficiency projects in more industrialized developing countries tend to cost less, due to the significantly greater cost reduction opportunities (World Bank 2003).

Private actors in the carbon market are extremely optimistic about its future; Point Carbon, a carbon market forecasting groups, predicts a robust market for Kyoto compliance credits with carbon prices steadying at about \$11 by 2010, even without US participation in the Kyoto Protocol (Point Carbon 2002). In a carbon market that operates outside of the regulatory framework of the Kyoto Protocol, analysts predict that carbon prices in the European Union might rise as high as €14 in 2007 (\$17 in 2004 dollars) (Point Carbon 2004). Other respected organizations and firms, such as ICF Consulting, Econergy, PricewaterhouseCoopers, and Det Norske Veritas concur that carbon prices are likely to rise steadily over the next several years. Contract sizes are becoming standardized, trade volumes are increasing each year, and more traders are entering the market, including those firms that have traditionally not taken an interest in environmental issues (PCF*plus* 2002; Point Carbon 2003).

According to the World Bank, the private sector has been reluctant to enter the market for carbon reduction projects under the CDM, primarily due to uncertainties related to the Kyoto Protocol's entry into force and lack of clarity about market rules (World Bank 2003). Consequently, the private sector makes only about 18% of all emissions reductions purchases in developing countries (Lecocq and Capoor 2002). LDCs, which encompass most of African nations, are largely bypassed by the carbon market. This may be linked to overall decline in foreign direct investment, the higher risks perceived in macro-economic climate in many developing countries, a long lead-time to prepare projects, and higher perceived transaction costs (PCF*plus* 2002). Presently, the private sector is much more likely to purchase emissions reductions either through large projects in India and Latin America or through public-private partnerships like the PCF, where risks and transaction costs can be dispersed across a large project portfolio rather than concentrated in one or two projects in smaller developing countries (Lecocq and Capoor 2002; PCF*plus* 2002; Michaelowa, Stronzik et al. 2003).

IV. Solar water heating

Many scientists, policy makers, and academics believe that solar water heaters are one of the most simple yet effective renewable energy technologies (UN 1992; IPCC 2001; Reddy 2002; Spalding-Fecher, Thorne et al. 2002). Indeed, these systems can often be constructed using locally available materials and with just a modicum of expertise and skill. Yet, their simplicity belies their potential to be a major contributor in efforts to reduce GHGs and stimulate local markets and macroeconomies.

The energy crisis in the 1970s stimulated vast amounts of research and development into new and improved renewable energy technologies (Yergin 1993; Hedger et al. 2001). Governments across the world created new programs, or strengthened existing ones, that focused on developing alternatives to fossil energy. The 1970s also produced innovative thinking on energy issues and the need to transcend the existing energy paradigm. Amory Lovins wrote his groundbreaking book, *Soft Energy Paths*, in 1977, and many grassroots activist organizations were formed around this time to help advocate for further work on renewable energy technology.

Today, scientists and researchers are pouring billions of dollars into highly sophisticated, state-of-the-art renewable energy technologies. Yet, one of the greatest renewable energy contributions to sustainable development is also one of the simplest and oldest technologies available: solar water heating systems. Solar thermal technology has existed, in varying degrees of complexity, for millennia. However, it did not evolve much beyond the most simple applications until the early 20th century, when Pasteur's germ theory, human migration into the solar-rich American West, and increasingly widespread use of dangerous and polluting coal- or wood-fired water heaters, among other drivers, necessitated a new look at the technology (Butti and Perlin 1980).

The global market for SWH has since blossomed. The European Union consistently exceeds targets for SWH adoption, and many other nations have embraced it strongly. In Israel, approximately 80% of the residential buildings are equipped with solar thermal systems, and in Turkey, over 630,000 m2 of SWH collectors are installed each year. Over 1,000 manufacturers in China service its domestic market – the world's largest, and 15% of Japanese homes use solar thermal technology to heat water

(ESTIF 2003). In other parts of the world, awareness of the benefits of SWH is growing, and adoption of the technology is growing in developed and developing countries alike.

For household SWH applications in many developing countries, a few standard designs stand out. The fundamental components of all SWH systems are a solar collector array, or absorber, an energy transfer system and a storage system. Passive, or 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. SWHs are also either direct (open loop) or indirect (closed loop) systems. Open loop systems circulate water directly through the collector, while closed loop systems use an antifreeze 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 preferable, due to their low cost, simple design, and longer life span – all factors that also facilitate local production and ease of use (Morrison 2002).

Three configurations of SWH exist: integral, close-coupled, and separate collector storage systems. In an integral or "batch" system, a single device functions as both a storage tank and heat collector. These systems are extremely cheap and simple (they can be a modest black tank exposed to the sun), though their primary disadvantage is their poor thermal insulation capacity, often resulting in an inability to store hot water once night falls, effectively losing any hot water supply for the late evening and early morning hours. These systems are not very popular, though some advanced models have enjoyed fairly good commercial success. In the close-coupled system, the collector abuts the hot water tank, and in the split collector system, the collector is separated from hot water storage tank. Either of these systems is usually preferable to the integral system, as the storage tanks tend to be insulated and can provide hot water well after the sun has set (Morrison 2002).

Solar collectors also vary in terms of complexity and cost. Unglazed collectors operate at relatively low temperatures and are best for applications such as heating swimming pools. Glazed flat plate collectors, while more expensive, fragile and heavy, are more ideally suited for residential applications. These are capable of generating relatively high water temperatures and are compatible with standard water main pressures. Evacuated tube collectors are even more complex and expensive, yet due to their superior performance in colder climates, they are growing in popularity, especially in China where they are produced at a relatively low price (RETScreen International 2001; Changzhou Skypower Solar Industry Co. Ltd 2003). In hybrid systems, which are popular where insolation levels and ambient temperatures are low, conventional energy sources supplement the user's hot water needs.

Benefits of Solar Water Heating

Environmental protection

Solar water heaters have a proven positive net impact on natural resources, both local and global (UN 1992; Mirasgedis et al. 1996; IPCC 2001). Yet, SWH technology has often been overlooked as a significant contributor to greenhouse gas emissions reductions. Some believe that SWH applications contribute more to emissions reduction and energy conservation than any other solar technology (Guiney 2002). Moreover, SWH technologies can also contribute to the achievement of many other sustainable development aims (Reddy 2002). The fundamental reason is that solar thermal energy reduces the need for other heating fuels by providing a heat source for household and commercial water heating needs. Even in cases where solar thermal technology is inadequate to fulfill all household hot water needs, it nevertheless reduces the need for conventional water heating fuels, creating a number of positive spillover benefits.

Since many rural households rely on fuelwood to meet their heating needs, an immediate environmental benefit of greater SWH use is that pressure on local fuelwood sources will decrease, supporting efforts to combat deforestation and desertification (UN 1992). While some evidence suggests that fuelwood collection for household use is not necessarily a major cause of deforestation and desertification (Chidumayo 1997; Sinha et al. 1998), as populations grow, dependence on gathered fuelwood can nevertheless degrade the local environment and have a widespread impact, such as injuring young trees and disrupting the resource base (Balachandran 2002). Reducing the burden on local woodlands can have other feedback effects, such as maintaining the ecological, economic, social and cultural roles of trees and forest ecosystems (UN 1992).

The introduction of SWH on a widespread scale can benefit the global environment, since it mitigates climate change by reducing consumption of fossil fuels, where they are a primary source of thermal energy (Interlaboratory Working Group 1997; Nadel et al. 1998; IPCC 2001). Lower demand for fossil fuels also means fewer emissions associated with their transport. In many developed and developing countries, around one third of a household's total energy consumption is used for heating water (Reddy 2001). In places such as China and India where coal-generated electricity is a common energy source for water heating, a SWH can prevent more than 50 tons of carbon dioxide emissions over its life span (IndiaSolar.com 2003), not to mention reductions in nitrogen oxide, sulfur dioxide, volatile organic compounds and other pollutants that power plants emit. Of course, replacing or supplementing water heaters fuelled by natural gas, liquefied petroleum gas (LPG), or other gaseous energy carriers also abates GHGs.

A Life Cycle Analysis that was applied to SWH concluded it is one of the lowest polluting renewable energy technologies that exists. Indeed, the only pollution that SWHs create occurs during the manufacturing process, which is much less energy intensive than the production of photovoltaic systems. Needless to say, the pollution that either of these technologies can claim over their life spans is vastly less than their conventional counterparts (Mirasgedis, Diakoulaki et al. 1996).

Economic development

SWH systems can also contribute to local economic development (Borchers and Engel 2002). Various agencies, such as the UNDP, UNEP, the World Bank, and national and regional development banks are investing in these programs around the world. Experience in East Asia shows that governments can help accelerate sustainable commercialization and generate potentially significant economic benefits by tapping local engineering strength and expertise, promoting transfer of foreign technologies, increasing local content in commercially available systems, supporting competitive and highly demanded technologies, and developing local and international markets (Balce 2001).

The promise of new markets for locally-made SWH technology and ancillary industries, such as retail outlets, service companies that install and maintain systems, and suppliers to local manufacturers of parts and materials is a primary driving force for such initiatives (MoFAoJ 1995; UNDESA 1999; Ecocity 2000; UNDP 2003; UNEP 2003). In stark contrast to wind and photovoltaics, SWH offers major employment opportunities to semi-skilled artisans, both in manufacturing and installation. In fact, a South African study finds that local SWH manufacturers currently operate at below half their total current capacity, and its authors conclude that if the national government implemented more ambitious targets for SWH penetration, over 355,000 new jobs could be directly and indirectly created by 2020 (Austin et al. 2003).

Local businesses also stand to benefit 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, and hospitals, among other businesses, have found that numerous profitable or cost savings opportunities exist in those sectors. Some low temperature applications (<35°C) include providing hot water for swimming and hydrotherapy pools, schools, public baths, gymnasiums, and other places with bathing facilities. Low temperature SWH technology is also commonly used for agricultural applications such as aquaculture, dairy, and brewing (RETScreen International 2001; UNDP 2002). In Zimbabwe, SWH is used in breeding ponds for crocodile farms. Medium temperature (35 to 60°C) applications have sanitary properties that can be useful in hotel culinary and laundry hot water supply and in commercial buildings (restaurants and toilets), industrial cafeterias and shower blocks. Low temperature process heat (60 to 100°C) has industrial applications, such as for bottle washing plants, commercial laundries, and food processing plants (McDiarmid 1999). SWH can also boost local tourism revenues. Hotels and resorts in temperate climates can advertise an extended swimming season, or just hot showers in some cases, helping to increase visitors. In rural areas where fuelwood is scarce, yet where tourists demand hot water, such as on a Himalayan trekking route, SWH can be a vital revenue generator (ESOK 2000; SIDSnet 2000).

On a household level, SWH system are often wise investments, if for no other reason than to displace conventional energy consumption. In many places in the world where solar insolation and conventional fuel costs are high, SWH equipment costs are often paid over a short period of time (Spalding-Fecher, Thorne et al. 2002; IndiaSolar.com 2003). Having a SWH system effectively increases the household's disposable income by reducing conventional fuel expenses, which permits spending for other important priorities that could potentially contribute to the household's well-being. Depending on the scale of the local microeconomy and the numbers of SWH owners, increased spending can have a positive effect on the economy (Schaffner 2002). A SWH system can also contribute to household-scale cottage industries. In parts of the world, fabric dyeing is a very hot water intensive service that many households participate in to earn income. Bangladeshi pilot programs have demonstrated that SWH systems can significantly defray the fuel costs for these entrepreneurs (Kamal 2004). Those who make soap, an activity that requires copious quantities of hot water, can also benefit from SWH (ITDG 2004).

Public health

Women are typically charged with the duty of collecting fuel, often spending many hours each day, with the help of their daughters, foraging for the family's immediate fuel needs (Clancy 2003). If the household's conventional fuel demand was cut back, the overall time burden on women will also be reduced, at least as far as gathering fuel for water heating is concerned. The time that is freed up from fewer or shorter trips to gather fuel can then be applied to other household needs (Reddy 2002).

The physical health of individuals and the entire household also dramatically improves with the introduction of SWH technologies. A major source of this benefit is, again, the reduced need for conventional fuels. Females typically carry the burden of stoking fires and tending to whatever it is that is being heated, such as food, water, dyes, etc. Consequently, they, and those in their vicinity, suffer inordinately from chronic respiratory disease associated with smoke inhalation (Reddy 2002). Since women tend to many of the most critical needs of the family, such as preparing meals, looking after the children, cleaning house, doing laundry, fetching water and fuel, to name a few, any illness that strikes them is likely to be felt across the entire household, the ripple effects of which could be detrimental (Clancy 2003). Thus, any reduction in their exposure to indoor air pollutants from fuelwood combustion will dramatically reduce their incidence of respiratory illness and can improve the overall well-being of the household (Weiss and Demmelbauer 1997).

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, as 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 many diarrheal diseases. Similar techniques were practiced in ancient India more than 2,000 B.C.E., and solar radiation for disinfection purposes has been reinforced in modern times (Acra et al. 1984). The degree to which the sun can disinfect water depends greatly on its maximum sustained temperature. Water exposed to the sun for several hours in a clear plastic or glass container can typically reach temperatures of up to 55°C, and both the sun's UV radiation as well as its thermal effects will inactivate many waterborne microbes (Joyce et al. 1996). However, most household SWH systems consist of an opaque container. In those systems, only thermal effects occur, but temperatures can reach 60°C or higher. At these temperatures, most enteric viruses, bacteria and parasites are rapidly inactivated, even within minutes (Ciochetti and Metcalf 1984). An added incentive to solar water pasteurization is the increased availability of labor due to healthier workers, and subsequent increases in agricultural output and income (Karekezi 2002). 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.

SWH systems can also contribute to larger efforts to support public health initiatives. For example, in Thailand, the government distributes SWH systems to the agricultural industry for the production of chemical-free pesticides and herbicides. Farmers use the hot water supplied by the systems to extract insect repellent substances from locally abundant herbs such as citronella grass, lemongrass and holy basil. In this context, SWH not only reduces the prevalence of chemicals in the country's food production, but it also reduces the use of conventional fuels, mainly LPG, that farmers normally use in the herbal extraction process. This process, of course, has other environmental and economic benefits. Moreover, allowing local firms to produce their own pesticides more cheaply and consistently will reduce the need for them to pay for chemical imports (Piyasvasti 2001).

Barriers to growth of SWH markets

The challenges that advocates of SWH face in their attempts to disseminate technology and build up markets are not unique to their experience. In fact, many other renewable energy endeavors face similar obstacles. Yet, due to the particularly low status that SWH technology has in most energy portfolios, they face special challenges. For example, in many developing countries, fossil fuels are predominant in national energy policy (DBSA 1999). Countries that do have a renewable energy policy often put little emphasis on solar thermal technology; some suggest that this is a function of the whims of the international donor community (Maegaard 2003).

Due to the low status of SWH systems, relative to conventional water heaters and even to other renewable energy technologies, there are a host of barriers to their successful inclusion in a national energy strategy. National institutions are often too weak to affect the kind of change that is necessary to support an entire industry or certainly a vast paradigm shift. The fiscal context in which SWH must operate often encourages – explicitly or not – the use of unsustainable fossil-fuel technologies for heating water, and a vacuum of pro-SWH policy prolongs the public's unfortunate association with mediocre equipment.

V. Analysis of carbon financing and solar water heating projects

Skeptics often question whether SWH can pass the barrier removal test. As explained earlier, a fundamental requirement for carbon finance to work is the knowledge of baselines for emissions due to energy consumption. In the case of water heating services in the developing world, such baselines are very difficult to come by, for several reasons.

1. Little data exists at all for demand for hot water in many developing countries, except in certain cases where government or NGO researchers have surveyed households or commercial and industrial enterprises. Where energy consumption data exists from energy utilities, it might be possible to extrapolate from energy use trends how much power is consumed for hot water services, but even such data is difficult to obtain.

2. In many parts of the developing world, individuals often heat water using non-commercial energy sources, such as from biomass that households gather or by purchasing it from an informal market. This practice is particularly true in rural areas, where access to electricity, natural gas, or LPG is sporadic or nonexistent. For countries such as India and China, the rural poor who depend solely on biomass comprise the majority. Moreover, it is difficult to

measure what percentage of a rural household's biomass consumption is devoted to heating water services.

3. Carbon emission factors (CEF) for biomass are not readily understood or defined, with values fluctuating between carbon neutrality and nearly 30 tons of carbon emissions per teraJoule, which exceeds even the CEF of bituminous coal, one of the most polluting fuels available (IPCC-NGGIP 1997; UNFCCC 2004).

4. Demand for water heating services is highly variable and depends on the prospective user's experiences and expectations.

Given these factors, few studies on the carbon intensity of water heating services in developing countries incorporate estimates of the carbon emissions that result from traditional biomass use for water heating purposes. In the face of this data void, the role that SWH services can potentially play in carbon finance is often neglected.

When assessing the potential benefit of carbon finance to SWH markets, it is also important to be able to predict the future market for the systems. However, in many contexts, performing an analysis of future markets conditions in developing countries can meet many challenges. For example, one must be careful not to assume that current market conditions will dictate future conditions. In many cases, there may be nascent demand that is not accounted for in baseline studies, but becomes apparent after the introduction of SWH (Kamal 2004).

Under the CDM

As noted, most proposed CDM projects thus far have been industrial-scale endeavors such as large hydro or coal power efficiency projects. With the exception of a few industrial applications, most SWH applications operate on a small residential or commercial scale. Consequently, project developers and investors have not explored many carbon mitigation options involving SWH, given their high carbon reduction potential. As mentioned above, delegates to COP-7 in Marrakesh established a legal framework for the streamlined incorporation of SSC projects into the CDM in response to calls for recognition of the need for specific rules for SSC projects (Agarwal 2000; Sokona and Nanasta 2000). Under the Simplified Baseline and Monitoring Methodologies approved by the EB for SSC projects, SWH projects are recognized as activity Type I.C: renewable energy projects that supply thermal energy to the end user[3] (UNFCCC 2003).

Key to assessing the CDM's potential to boost SWH markets is the all important question of whether SWH can pass the barrier test. Unfortunately, programs or projects designed to promote widespread penetration of SWH technology often fail due to a number of barriers. The most pervasive barriers are often related to high upfront cost, technology failures, non-supportive public policies, and weak institutions – all barriers that the CDM EB has identified in the additionality criterion (UNFCCC 2003). The good news is that the EB has established that any "project

[3] Some project developers have suggested that establishing baselines for SWH systems is one of the most challenging steps in preparing a PDD. Developers in South Africa are currently grappling with the decision on what baseline methodologies to use. They are attempting to secure CDM financing to retrofit low-income housing units with solar water heating systems but have had a difficult time determining an appropriate baseline. The dilemma they face is that most of the common conventional water heaters used on the project site are kerosene-fired, which emit relatively low amounts of carbon dioxide. Due to kerosene's low carbon emission baseline, the total amount of CERs that that project can generate is quite low. However, the hot water service from kerosene heating is widely considered inadequate, and the project developers speculate that the community will, in the absence of intervention, install electric water heaters, which rival SWH in their service quality and are available at a lower upfront cost; a transition from kerosene to electricity will clearly result in increased emissions, not less. For more information about this project, see Randall Spalding-Fecher, Steve Thorne, et al. (2002). "Residential Solar Water Heating as a Potential Clean Development Mechanism Project: A South African Case Study." Mitigation and Adaptation Strategies for Global Change **7**: 135-153.

activities" – SWH technology, in this case – that have been traditionally hindered by any of those barriers have met an important criterion for securing CDM approval.

The four barriers that the EB included as part of the additionality test are related to investment, technology, prevailing practice, and "other;" indeed, as noted in the previous section, each of these barriers has traditionally impeded growth of SWH markets in developing countries. Even though the EB has classified the barriers to renewable energy diffusion into four relatively distinct categories, almost all of them are interconnected, and many cannot be cleanly categorized. For example, investment barriers are as much a function of prevailing practice as anything else, while barriers due to prevailing practice cannot exist separately from the institutional, economic, and even social environments within which the energy sector operates.

Investment and price-related barriers

An "investment barrier" is one that results in the market's greater acceptance of less expensive, but more polluting technologies (UNFCCC 2003). Under current market conditions in many countries, it is cheaper for homeowners to install standard electric or gas water heaters, which will always emit more greenhouse gases than SWH. Life cycle costs, though, often favor solar over conventional water heating in areas with high levels of insolation, expensive conventional fuel, and where freezing conditions are infrequent or non-existent. Examples of investment barriers also include cases where the return on equity of clean energy is too low for investors compared to conventional projects, where real and/or perceived risk associated with the unfamiliar technology or process is too high to attract investment, and where funding is not available for innovative projects.

Empirical evidence suggests that the cost of high-quality SWH technology is prohibitively high for many in the developing world (NAHB Research Center Inc. 1998; DBSA 1999; Spalding-Fecher, Thorne et al. 2002; ESTIF 2003; PRESSEA 2003). In many developing countries, the local private sector has very little capacity to manufacture, distribute, install, and maintain high quality SWH systems, and the dependence on imported systems creates a market in which the only available equipment is often priced well beyond the means of the average consumer (GEF 1999).

Many people who would consider borrowing money to pay the up-front cost for SWH equipment are unable to do so because of structural limitations in the banking system. For example, banks do not often have the capacity and expertise to process small loan applications for individuals wishing to purchase SWH systems. For loans to new home buyers, banks might set the loan ceiling based only on conventional costs, thus giving them few options. Experience from Namibia shows that banks are unwilling to offer additional loans for SWH systems, because loan officers are unaware of the relative increase in the loan applicant's income by virtue of having a SWH system. Moreover, bankers might fail to factor the benefits of SWH systems into a home's value and poor communication within the banking sector can undermine the system's merits. In addition, government subsidies might not allow for installation of non-conventional technology (GEF 2002). Financial barriers also deter commercial investors from considering SWH systems for larger applications (GEF 1999).

The most cited reason for the failure of SWH systems to take hold is the prevalence of low energy tariffs in many countries (Reddy 2001; Spalding-Fecher, Thorne et al. 2002). Artificially low prices for electricity (and conventional water heating equipment) will almost always relegate SWH systems to the market's periphery, since manufacturers of those systems do not often have the luxury of receiving large government subsidies (DBSA 1999). Researchers also often cite the low economies of scale related to SWH for the high prices of SWH systems in developing countries (GEF 2001;

OPET-TERI and HECOPET 2002). Due to the small markets that exist in many countries, bulk procurement and imports of SWH systems and their components are very limited, thereby resulting in low volume and high prices. Also, the lack of household-scale financing schemes also prevents the economies of scale necessary to stimulate SWH markets (Grameen Bank 2003).

Investment barriers might also incorporate some of the following: lack of well marketed, affordable and easily accessible financing for the purchase, installation, and maintenance of SWH technology; lack of skills to develop business plans for the supply, manufacture and use of SWH systems; and local financiers' limited knowledge of local, regional and international bulk lending facilities, modalities, instruments, or lines of credit dedicated to clean development of supply and efficient use of cleaner energy. Other factors might include a lack of confidence in the returns on investment (for end-users) and loan performance (for financiers), and inaccurate comparisons of costs between SWHs and business-as-usual technologies for equivalent energy services. As a result of these conditions, typical prices of SWH systems are often much higher than conventional electric or gas systems, and even though there are virtually no daily costs of operating SWH, cheap conventional water heating technologies serve as a disincentive for buyers to choose or switch to SWH systems (Vipradas 2001; Spalding-Fecher, Thorne et al. 2002).

Technology or product-related barriers

According to the EB, a proposed project faces a "technological barrier" if "a less technologically advanced (and presumably less efficient) alternative to the project activity (SWH, in this case) involves lower risks due to the performance uncertainty [of the new technology]…" *(parenthetical comments added)* (UNFCCC 2003). However, SWH systems turn the CDM's technology barrier onto its head, as SWHs are in fact likely to be less technologically advanced than the prevailing technology. Still, some SWH systems do integrate a conventional heat back-up, adding an element of technical complexity compared to stand-alone conventional systems.

To a certain degree, the technology's own limitations is a major barrier to the greater dissemination of SWH systems. It is not appropriate for all climates, and its ability to heat and store hot water fluctuates depending on a wide range of conditions. Further, due to some circumstances, external markets notwithstanding, some SWH systems are quite complex and can be more expensive than conventional systems. For these reasons, SWH is not universally accepted.

There are barriers to the dissemination of SWH that are not linked with the technology's natural shortcomings. For example, few governments in developing countries are able to adequately control the quality of SWH equipment in their markets. Thus, the absence of norms, standards, certification, codes of practice and performance contracts for SWH systems reduces many incentives for manufacturers to produce and sell high-quality equipment (ESTIF 2003). The GEF has determined that in Morocco poor quality SWH systems can delay, or in the worst case, permanently stifle long-term development of the whole sector (GEF 1999).

Even when many SWH products on the shelf are high quality, many people still have gross misconceptions about the technology. Indeed, there is a general perception among the public in many countries that SWH technology is inherently flawed and is therefore not worth seriously considering as viable alternatives to conventional water heating systems. This stems partly from the many failed projects dating back to the 1970s and '80s when immature and poorly-made systems flooded developing countries, and a general failure of project developers to pay attention to the needs of SWH users. Moreover, most projects were initiated and executed under strict conditions, and as a result, few succeeded in the open market without massive intervention (NAHB Research Center Inc. 1998; Hedger, Martinot et al. 2001; ESTIF 2003). Others even suggest that the low opinion of SWH technology is part of a campaign of misinformation on the part of pro-fossil-fuel groups (Maegaard 2003).

In many countries, the poor image of SWH is partly due to poor product placement. The GEF has found that the market for SWH is often grossly distorted simply because cheaply made and inexpensive systems are presented to the buyer, without comparison, along with more expensive but far superior systems. As a result, it is nearly impossible for consumers to accurately judge the equipment on a rational price/quality ratio. Thus, under these asymmetrical information conditions, a rational consumer would naturally purchase the less expensive system, which will often fail and leave him with a lasting negative impression of SWH technology (GEF 1999).

Fundamentally, low sales volume, the low profitability for dealers of SWH systems, and indifferent public policy encourages the use of sub-standard quality products, simply because profit margins are so low for more expensive systems. This perpetuates consumer perception that SWH are inferior products, even if they are demonstrated to be cost-effective alternatives to conventional water heaters (GEF 1999).

Barriers due to prevailing practices

The fact that a more expensive, more polluting technology has the current monopoly over worldwide water heating services is mostly a function of what the CDM EB calls a "barrier due to prevailing practice." In the case of the CDM, this barrier exists when a cleaner technology is unable to compete on a level playing field due to a "prevailing practice or existing regulatory or policy requirements" (UNFCCC 2003). For example, many country governments subsidize their energy utility companies. Governments typically levy high tariffs against imported technology, and renewable energy technology is usually not immune to this sort of protection. Consequently, clean energy technology, such as SWH systems, are often priced above locally manufactured or favored imported conventional water heaters (Reddy 2001). Also, a barrier due to prevailing practice might exist when developers lack familiarity with state-of-the-art technologies and are reluctant to use them.

Other barriers

Other national characteristics that do not fall into the above categories might also hinder greater market penetration of SWH technology in a developing country. For example, countries that have weak institutions are often unable to effectively apply policies that promote alternatives to the status quo. They might also have little resources to establish quality control standards for new technology, as well as few mechanisms to spread awareness about SWH promotion programs, if they were to exist. These barriers fall into the EB's "other" category, and SWH CDM project developers may apply them to the additionality test as well and claim them as hindrances to SWH project activity (UNFCCC 2003). Additional barriers that might fall into the "other" category could be when management lacks experience using newer technologies, so such projects require excessive resources to handle and thus receive low priority by management. "Other" barriers also might exist when the local community fails to see the environmental benefits of SWH and therefore opposes any effort to reduce their use of conventional fuels.

Weak institutional capacities frustrate efforts to create a sound environment in which markets can flourish. Fundamentally, there are often too few well-trained personnel to properly maintain the institutional momentum needed to make the political changes that are necessary to foster a truly enabling environment. Few people in government, even in the energy ministries, have little empirical knowledge of the benefits and costs of SWH technologies (GEF 1999). This translates into a distinct knowledge gap that extends to energy providers and potential customers. Consequently, society is often ill-equipped to properly evaluate all of its options for sound energy consumption practices. An Indian survey of household and commercial users of SWH systems revealed that the biggest barrier to further SWH dissemination was a "lack of awareness and information" about the technology, financial incentives, and other related policy measures. Many people suggested a "need for better institutional structure to diffuse usage of SWH." Indeed, for many, newspapers and magazines were the primary source of their information (Reddy 2001).

Studies have shown that a lack of coordination between the various actors in the SWH industry and buyers detract from the industry's ability to become successful PRESSEA, 2003 #132}. In many countries, the private sector, collectively, lacks the capacity it needs to maximize its potential. In Thailand, for example, the chain is often so weak that some buyers of SWH equipment receive no after-sales services at all (PRESSEA 2003).

Architects and developers are often not equipped to recommend SWH technology for new homes because of unfamiliarity with the technology or preconceived notions they might have about its performance. A study from Namibia on barriers to SWH use in the home building industry found that builders are often unaware or do not have information on the monetary and environmental life-cycle costs and benefits of SWH versus electric geysers. They are also often not informed about reliability, product longevity, long-term performance, product quality, and enforceable performance guarantees of SWH systems. Homeowners rarely demand SWH when building or buying a house or purchasing a new water heater, because they too are unaware of the these issues (GEF 2002).

Specific CDM-related barriers

High transaction costs for CDM projects are likely to prove detrimental to SSC and SWH projects. A study by Michaelowa, et al. indicates that mini and micro projects, such as energy efficiency for households and small to medium scale enterprises, mini hydro, PV, and ostensibly residential SWH systems, will generate transaction costs from €100 to €1,000per ton CO_2e. Without measures to significantly reduce these costs, such projects will undoubtedly prove unviable from a cost recovery perspective. However, special institutional settings or activities to streamline the project cycle, as outlined above, can reduce these costs significantly and enable some SSC projects to flourish (Michaelowa, Stronzik et al. 2003). While details for how this standard methodology will be applied must still be provided by the project developer, the existence of SWH as an SSC activity category with an approved methodology creates the opportunity to trim costs by skipping a step in the project development process, i.e., the step of having a proposed baseline methodology reviewed by the CDM Methodology Panel and EB.

Paradoxically, the CDM's very own additionality requirements might prove detrimental to climate friendly sustainable development efforts. Studies of experiences in Latin America and the Caribbean have found that the additionality requirement often serves as a disincentive for developing countries to implement clean energy projects by rendering such projects CDM-ineligible. For example, developers of decarbonizing projects in Mexico City hold back out of fear that the projects would not qualify for possible CDM financing (Point Carbon 2004), and Costa Rican authorities are finding that some potential CDM projects might be deemed non-additional, because environmental policy has already been introduced in several key fields (Point Carbon 2003). One way to remedy this problem is for the CDM EB to accept the establishment of sectoral carbon efficiency standards in developing countries' most carbon intensive sectors. If this were the case, any project that would be upgraded to attain the higher sector could be eligible for CDM project status (Samaniego and Figueres 2002).

Despite reforms made to the CDM in the Marrakesh Accords, the world's LDCs are still at a significant disadvantage in attracting SSC CDM investment. Observers have noted that some of these disadvantages can be eliminated or reduced by allowing future emissions to be counted in baseline estimates. In many LDCs where current carbon emissions are negligible but where there is a desperate need for energy, such a clause could greatly enhance these countries' competitive position, attracting investments that would otherwise go elsewhere (Sokona and Nanasta 2000). This is especially true as various actors begin supporting a greater use of fossil fuels to meet these countries' energy needs (Davidson and Sokona 2002).

In the past, market-based emissions reduction projects, carried out under the auspices of Activities Implemented Jointly, were almost exclusively taken up in more industrialized, non-Annex I countries such as Brazil, India and China (Sokona et al. 1997). However, poorer regions such as Sub-Saharan Africa (excluding South Africa) are consistently overlooked for CDM investment. Regional-based quotas could be critical for these areas to have its fair share of CDM projects. Similar quotas should apply equally to the "share of the proceeds from certified project activities that is to be used to assist developing country Parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation" (UNFCCC 1997).

Additional critiques of the sustainable development prospects of the CDM suggest that the Parties should place a limit on the percentage of fossil fuel efficiency projects from which Annex I countries can claim emissions reductions credits. Some analysts might even go so far as to say that CDM financing should be restricted only to projects that promote the "zero-carbon energy system." The logic is that investments in fossil fuel efficiency will lock countries into the carbon energy sector for decades, defeating the purpose of the UNFCCC, which aims to reduce emissions primarily through, among other things, using less carbon-based fuels. Moreover, one must consider the opportunity cost of investing in fossil fuel technology; ostensibly, renewable energy technologies will be underfunded while slightly cleaner fossil fuel technologies are subsidized, further locking developing countries into fossil fuels (Agarwal 2000).

Others suggest that the current design of the CDM EB is not advantageous to LDCs. While there are a number of features that can be included in the CDM's governing architecture,[4] most observers in the developing world support a system that creates an independent intermediary between the host country and the Annex I investor. Called a Single-Supplier or Multilateral Arrangement, this system would give developing countries the greatest control over CDM investment flows within their borders by ensuring that the differing needs of all parties are considered (Sokona, Humphreys et al. 1997). Additionally, such a body could take an active role in channeling investment into emissions limiting projects that may not yet be commercially viable (Sokona, Humphreys et al. 1998).

4 For more information about the various types of models for the CDM, see "Designing the Clean Development Mechanism to Meet the Needs of a Broad Range of Interests" by Kevin Baumert and Nancy Kete. World Resources Institute, 2000.

For many LDCs, one of the most promising components of the CDM is its call for enhanced capacity building. An effective organizational and administrative infrastructure is vital to a country's greater developmental goals as well as for ensuring the capacity to form and execute action that is consistent with the Convention's goal of combating climate change. Sustainable development is simply not the happy result of a flurry of well-designed projects, but rather the product of dedicated efforts to establish lasting institutions. For instance, one important benefit the CDM can bring to that end is to provide funds that support the development of internal markets for clean technology goods and services (Orawo 2001).

Some advocates of greater renewable energy activities in developing countries do not see the CDM as a panacea. Critics suggest that the CDM, in its current form, does not adequately maximize GHG reduction opportunities; they cite the CDM's incorporation of carbon sinks, coal power, and large hydropower projects as contrary to the Kyoto Protocol's mission of drastically cutting global GHG emissions (Agarwal 2000; CRID 2003). Moreover, they claim that participation by non-Parties to the Kyoto Protocol undermines its legitimacy, thus weakening international efforts to establish an effective and globally binding carbon reduction mechanism (CDM Watch 2003; CRID 2003).

Under the CDCF

The CDCF is still a relatively new institution, and the breadth and depth of its impact has yet to be truly felt across world carbon markets or in rural areas where energy services are desperately needed. When the Fund became operational in July 2003, it had commitments of $35 million from both public and private sector participants. A handful of the usual participants – the Dutch and Canadian governments, for example – and some Japanese companies had made commitments by the Fund's first day in operation (World Bank 2003), and the World Bank expects to have $100 in commitments by the end of 2004.

The CDCF strives to serve as a main driver in efforts to accelerate developing countries' participation in the carbon market, and it just might do that. Its theoretical ability to leverage millions of dollars toward SSC renewable energy projects in the developing world is astonishing. It is promising in that it is one of the first large-scale endeavors to specifically address the needs of the developing world, and particularly the LDCs.

An added benefit the CDCF brings to SSC projects such as SWH is that thanks to the enormous resources of its progenitor, the World Bank, it can afford to invest in projects where players in the open market might not find it worthwhile. Its ability to be flexible in the face of unfriendly market conditions is a testament to the Bank's willingness to increase its tolerance to risk where the world's neediest are concerned. Nevertheless, the World Bank group does have strict requirements for projects in which it disburses loans and grants, and the CDCF's status as a World Bank entity might still limit its ability to make all but the safest investments (Lundgren 2004).

World Bank participation in SSC renewable energy projects might provide the boost that many markets need to become established and sustainable. Transparency and good governance have become dominant themes in the World Bank group, and it is likely that countries participating in the CDCF will strengthen the institutions that regulate and support renewable energy efforts (Lundgren 2004).

Funders seeking to participate in the CDCF that take into account the uncertainty about the Kyoto Protocol often believe that holding high quality emissions reductions provides an insurance policy of sorts, since those reductions are more likely to be recognized by future GHG emissions regulatory regimes. Finally, others recognize that climate change is a long term global problem requiring the support of all countries and communities, no matter how small. Activities such as those embraced by the CDCF to include even remote or marginalized communities in efforts to mitigate climate change are necessary to build a global constituency for action that must be sustained for generations in order to be effective (World Bank 2003).

Other carbon trading schemes

Besides the CDM and CDCF, other carbon finance programs and similar mechanisms could be used to help boost markets for SWH systems in developing countries. For example, U.S.-based programs like the Climate Trust of Oregon and the Chicago Climate Exchange enable emission reduction procurement from projects beyond the US borders, and plans are being developed for a regional cap and trade program in the Northeastern United States that might have similar provisions. While carbon offset programs currently operate on a small scale, there is still tremendous potential for them to assist in surmounting investment barriers to wider SWH dissemination. Furthermore, governments that are having a difficult time meeting their renewable energy portfolio standards might be inclined to purchase green credits from renewable energy developers, if and when program rules allow for this.

VI. Case studies

In an effort to better understand how SWH markets have fared in the absence of carbon finance thus far, I examined a cross-section of countries where the technology is currently being used.

Specifically, I looked at the following fifteen countries: Barbados, Brazil, Chile, China, Costa Rica, India, Mauritius, Mexico, Namibia, Nepal, Peru, South Africa, St. Lucia, Tunisia, and Turkey. I sought to determine what the conditions for a synergistic relationship between an international carbon trading regime and SWH systems might be. In order to make accurate comparisons between those countries I examined, I compared them as a group, asking identical questions about each. The questions were the following:

- What SWH systems are available?[*]
- What are their up-front costs?[*]
- To what degree have SWHs penetrated water heating services markets?[♦]
- What are the conventional water heating systems available on the market?[*]
- What are the up-front costs of conventional water heating systems?[*]
- What is the cost of conventional fuel, and what is its place in the market?[♠]
- If electricity is used to heat water is, is it derived from hydropower, coal, or gas, for example?[♥]
- What are the demographics of those who consume hot water, and who among those use SWH systems?[♦]
- Are there government-sponsored incentives for purchases of SWH systems?[♣]
- What are some estimates of greenhouse gas reductions that have been determined after use of SWH systems?[☻]

∗ I gathered data on these points from a variety of primary sources, such as via manufacturers' websites and direct email inquiries to manufacturers and retail outlets. In some cases, I refer to data included in third party studies and other reference materials that I received from research institutes, non-governmental organizations, government agencies, and from the Internet.

♦ For information on penetration rates of SWH technology, national demographics of hot water users, and data relating to installations of SWH systems, I relied almost entirely on studies that examined country-specific aspects of renewable energy diffusion. These sources were often government agencies or intergovernmental entities, such as the World Bank.

♥ I obtained the bulk of my data pertaining to conventional energy costs from government agencies or private utilities. For electricity prices, I relied heavily on the US DOE's online figures found at: http://www.eia.doe.gov/emeu/international/elecprih.html. For natural gas or LPG prices, I collected data from the relevant national energy agency or utilities.

♠ I found this information on the website of the United Nations Statistics Division: http://unstats.un.org/

♣ This data was most often available from government ministries or from third party studies.

☻ In determining carbon abatement, I often used more than one information source. For some countries, such as China and India, I found data that described exactly what quantity of carbon was abated from utilization of SWH

Adequate data was unavailable for all countries, so I chose to highlight the five countries for which the most trustworthy and comprehensive data was available: Barbados, China, India, Mexico, and South Africa.

Country studies

Table 2: Country data

	Country	data source	retail cost per liter	# of liters in average system	average cost of system	tons co2 abated/100L/yr	tons co2 abated/100L/ 10 yrs	CER revenue per system at $5/ton	CER value (% of cost if C02 at $5/ton)	CER revenue per system at $10/ton	CER value (% of cost if C02 at $10/ton)
ten year period	Barbados	Government	$ 4.95	363	$ 1,797	0.91	9.1	$ 165	9%	$ 330	18%
	China	Xiao	$ 1.45	180	$ 261	0.586	5.86	$ 53	20%	$ 105	40%
	China	Xiao	$ 1.45	180	$ 261	0.837	8.37	$ 75	29%	$ 151	58%
	China	US embassy	$ 2.17	150	$ 326	2.38	23.8	$ 179	55%	$ 357	110%
	India	MNES	$ 3.50	100	$ 350	1.5	15	$ 75	21%	$ 150	43%
	Mexico	Quintanilla	$ 5.66	300	$ 1,698	0.59	5.9	$ 89	5%	$ 177	10%
	Mexico	Sunway	$ 5.66	265	$ 1,500	0.94	9.4	$ 125	8%	$ 249	17%
	South Africa	SSN	$ 5.63	150	$ 844	0.96	9.6	$ 72	9%	$ 144	17%

	Country	data source	retail cost per liter	# of liters in average system	average cost of system	tons co2 abated/100L/yr	tons co2 abated/100L/ 14 yrs	CER revenue per system at $5/ton	CER value (% of cost if C02 at $5/ton)	CER revenue per system at $10/ton	CER value (% of cost if C02 at $10/ton)
fourteen year period	Barbados	Government	$ 4.95	363	$ 1,797	0.91	12.74	$ 231	13%	$ 462	26%
	China	Xiao	$ 1.45	180	$ 261	0.586	8.204	$ 74	28%	$ 148	57%
	China	Xiao	$ 1.45	180	$ 261	0.837	11.718	$ 105	40%	$ 211	81%
	China	US embassy	$ 2.17	150	$ 326	2.38	33.32	$ 250	77%	$ 500	154%
	India	MNES	$ 3.50	100	$ 350	1.5	21	$ 105	30%	$ 210	60%
	Mexico	Quintanilla	$ 5.66	300	$ 1,698	0.59	8.26	$ 124	7%	$ 248	15%
	Mexico	Sunway	$ 5.66	265	$ 1,500	0.94	13.16	$ 174	12%	$ 349	23%
	South Africa	SSN	$ 5.63	150	$ 844	0.96	13.44	$ 101	12%	$ 202	24%

	Country	data source	retail cost per liter	# of liters in average system	average cost of system	tons co2 abated/100L/yr	tons co2 abated/100L/ 21 yrs	CER revenue per system at $5/ton	CER value (% of cost if C02 at $5/ton)	CER revenue per system at $10/ton	CER value (% of cost if C02 at $10/ton)
twenty-one year period	Barbados	Government	$ 4.95	363	$ 1,797	0.91	19.11	$ 347	19%	$ 694	39%
	China	Xiao	$ 1.45	180	$ 261	0.586	12.306	$ 111	42%	$ 222	85%
	China	Xiao	$ 1.45	180	$ 261	0.837	17.577	$ 158	61%	$ 316	121%
	China	US embassy	$ 2.17	150	$ 326	2.38	49.98	$ 375	115%	$ 750	230%
	India	MNES	$ 3.50	100	$ 350	1.5	31.5	$ 158	45%	$ 315	90%
	Mexico	Quintanilla	$ 5.66	300	$ 1,698	0.59	12.39	$ 186	11%	$ 372	22%
	Mexico	Sunway	$ 5.66	265	$ 1,500	0.94	19.74	$ 262	17%	$ 523	35%
	South Africa	SSN	$ 5.63	150	$ 844	0.96	20.16	$ 151	18%	$ 302	36%

systems. In some other cases, I calculated carbon savings using data of available conventional fuel and quantities of fuel saved. In order to standardize the results, I made all figures for carbon savings in per 100 liter measurements.

Barbados:

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 penetration is partly due to the country's relatively high rates of insolation, some of the highest electricity prices in the world, and very active government programs promoting the use of SWH technology.

Almost all of Barbados's 78,000 households are connected to a national grid, and the most common energy source for water heating is electricity, 99% of which is generated by the combustion of imported oil (UN-HABITAT 1999; Ince 2000; UNSD 2004). Electricity prices in Barbados are high, with average rates of around 17.5 cents per kWh (Ince 2000; EIA 2004). The SWH systems used in Barbados are thermosyphonic, and most consist of a flat plate collector and separate tank, though there are some integrated collector systems on the market. Both are open systems, meaning that water is heated directly in the collector.

The post-incentive price of SWH systems in Barbados is relatively low, though retail prices are moderate. Typical up-front costs for household-sized SWH system in Barbados are around $1,800, or roughly $4.95 per liter of capacity (Ince 2000; Sunpower Hot Water Systems). To bring down costs, the government offers vendors a preferential import regime and tax holidays, and it gives local SWH manufacturers special rates for almost all materials that are used in the construction and repair of SWH systems, including fiberglass, copper, aluminum, as well as more specific items such as hot water storage cylinders, solar collectors and water based adhesives. To buyers, the government offers a 100% rebate on the cost of the systems on their national income taxes (Ince 2000; Government of Barbados 2001).

The total energy savings that is attributed to each of the roughly 32,000 systems is around 4,000 kWh per year, keeping a total of around 97,000 tons of CO_2e out of the atmosphere, or 0.9 tons of CO_2e per 100 liters of capacity (Government of Barbados 2001).

Generally, CDM projects that are based on SWH projects are not likely to take place in Barbados. Barbados has a very well developed market for SWH technology, and it has done so thus far in the absence of an internationally binding climate regime and carbon finance. Up-front costs for SWH are not particularly high, compared with some other countries, and with a GNI PPP per capita of over $15,000, Barbadians are generally well equipped to afford these systems. The institutional will in Barbados to promote SWH is very high, and in terms of promotion of renewable energy technologies, the government is one of the most active in the Caribbean. As noted above, it has undertaken extensive efforts to give solar technologies an advantage in the Barbadian market for water heating systems.

However, despite the country's success with promoting SWH, it must be noted that almost 14% of the country's population lives in poverty, and over 60% of homes still lack SWH systems (World Bank 2004). Even with generous government pro-SWH policies, buyers must still make an average up-front payment of $1,800 to purchase a system, which they will only recoup in the form of tax savings. However, because the subsidy is linked to income taxes, households that do not earn enough income to file income taxes are unable to take advantage of the government subsidy. In this context, it can be argued that there is still indeed an investment barrier in place in Barbados, albeit for a minority of the population. Examining the data in Table 2, one can see that given this rate of carbon abatement and the up-front cost of systems, that sales of CERs from standard SWH systems at $5 per ton of CO_2 over a 21-year crediting period will still cover 19% of system costs.

The national government has identified the tourism sector as a potential target for CDM funding, due to its enormous carbon abatement potential, but it has yet to submit specific proposals to the CDM EB (Government of Barbados 2001). However, most Barbadian hotels already use SWH systems (Government of Barbados 1999), so CDM financing to the hotel sector may not pass the additionality test.

China:

China is one of the world's biggest players in the production and consumption of SWH systems. In 2002, production reached 8 million m^2 – an increase of 66% over 1999 production. With less than 1% of the national SWH production being exported, the accumulated installed area of solar domestic hot water systems in China as of 2002 was about 40 million m^2 (ESTIF 2003).

However, despite the relatively low prices of SWH, conventional systems are still the norm. Almost three quarters of all hot water in China is obtained via a manufactured hot water heater, and the vast majority of those systems are instantaneous gas systems (Brockett et al. 2002). Gas systems are gaining popularity in urban areas, as system efficiency has improved and as more households gain access to piped natural gas supplies (Li 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 are consequently more popular (Li Hua 2002).

Regional and national governments have traditionally put a premium on providing natural gas and electricity supplies to the public at low rates (Logan and Dongkun 1999; EIA 2004). However, the costs of electricity and natural gas has been increasing in recent years as a result of an increasing reliance on market mechanisms and aggressive measures to improve air quality, such as encouraging energy efficiency (Sinton and Fridley 2001; Logan and Xiucheng 2002).

The most common SWH systems on the domestic market in China have standard glazed flat plate collectors and are passive integral, close-coupled, or split collector systems. The average cost for such systems is $1.45 per liter of capacity (Li Hua 2002; ESTIF 2003). Chinese manufacturers also produce more expensive systems with vacuum tube collectors, but these systems are predominately destined for the export market, though they are gaining popularity among China's growing middle class (ESTIF 2003). At an average price of between $2 to $3 or less per liter of capacity, these vacuum tube systems are still well below the world average for basic flat plate systems (US Embassy Beijing 1998; Li Hua 2002; Changzhou Skypower Solar Industry Co. Ltd 2003). A survey of available data suggests that the average carbon abatement potential per 100 liter system can be nearly 2.5 tons of CO_2e.

Although there are no direct government subsidies for SWH manufacturers in China, the solar thermal market is on the rise (Xiao et al. 2004). The government has been pursuing aggressive public awareness campaigns and has established a nationwide network of technical service centers where consulting and training is available for those involved with SWH technology. The government has also implemented stringent quality control standards for SWH systems and has offered generous financial incentives for its manufacturers (Sinton and Fridley 2001; ESTIF 2003).

Despite the fact that China in the biggest producer and consumer of SWH technology, over 200 million Chinese still lack access to hot water supply (Junfeng 2003), and the SWH industry faces some fundamental barriers for future growth, all of which could qualify China for SWH-related CDM financing. Predominantly, the prices of new SWH systems are still beyond the reach of many ordinary Chinese. Moreover, few opportunities for up-front financing exist in China, and when it does, high interest rates and short payback periods often prove prohibitive for poorer Chinese households. If carbon finance were to be applied to domestic SWH and the market price of CO_2 was $10 per ton, their owners would be able to cover their costs over twice over a 21 year crediting period. Even with CO_2 prices at just $5 per ton and credited over only a seven year period, carbon finance could reduce up-front costs for SWH systems by 20 to 55%.

Low quality products still proliferate on the Chinese market, despite the fact that the government has established quality standards for SWH systems. Clearly, however, not enough has been done to comprehensively improve the quality of Chinese systems. Another hindrance to further SWH dissemination in Chinese households is the lack of communication and coordination between manufacturers and the building industry. China has identified the need to better integrate SWH in new residential and commercial developments, but a large gap still exists (Graham 2001; Junfeng 2003).

There are many institutional barriers in the Chinese banking sector, and a result, the SWH industry struggles to attract commercial financing. This is a function of at least two issues: low levels of awareness among financiers of potential investment opportunities, and an inability of SWH manufacturers to adequately court prospective investors. Also, where credit is available, loan pay-back periods tend to be inappropriately short (Graham 2001).

Because government entities, NGOs, and private corporations are actively engaged in efforts to overcome some of the barriers that are stifling greater growth of the Chinese SWH market, additionality could become an issue if project developers attempt to receive CDM financing. Still, additional resources are still needed to supplement the modest efforts of the above parties, especially where investment barriers are predominant.

India:

India is well positioned to exploit the vast potential of demand for SWH systems among households, as SWH is already one of the most commercialized renewable energy technologies in India (ESTIF 2003), and the economies of scale that will come from the industry's further development will drive down prices even further. However, most SWH applications in India are in the commercial and industrial sector, and households account for only 20% of all installations (OPET-TERI and HECOPET 2002; ESTIF 2003; Kamal 2004).

India is a predominately rural country that lacks a comprehensive national electric or natural gas distribution system. Consequently, over half of all households have no regular access to electricity, and liquefied petroleum gas (LPG) supplies to rural areas can be infrequent and prohibitively expensive (IEA 2002; UNDP 2003). Therefore, in rural areas where there is demand for hot water services,[5] households must rely on non-conventional energy sources. In many cases, this means burning biomass inefficiently – often dung, fuelwood, or agricultural waste – in an open stove and

5 Demand varies greatly in India, not unlike the situation in many large developing countries with diverse regional situations. Various factors that contribute to the differences in regional hot water demand are climactic conditions, cultural habits, prevalence of hot water-intensive manufacturing activity, and household income (Kamal 2004).

putting household members as risk of respiratory disease (Goldemberg 1996; Reddy 2002; Varughese 2004). Surveys have established that there is indeed a demand for hot water even in desperately impoverished areas, and there is a willingness to pay for the services (ESTIF 2003).

Where households are connected to the electric grid, electricity is the most popular energy source to heat water, with 90% of respondents to a UNEP-sponsored survey noting that they rely 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). As expected, areas are near large hydroelectric dams do, for example, tend to have lower tariffs than more remote areas. Still, overall, electricity tariffs are quite low relative to other developing countries, with average rates of around 2.4 cents per kWh (WEC 2001; EIA 2004). However, electricity prices in India are increasing steadily (Vipradas 2001; ESTIF 2003), which serves to increase the competitiveness of SWH versus conventional electric systems.

In the household sector, most SWH systems are very basic passive thermosyphon systems with simple glazed flat panel collectors. Some vacuum tube collectors have been introduced into the market, but these are imported and are considerably more expensive than domestically-produced flat panel glazed systems (ESTIF 2003). Quality of the systems is quite high, thanks to the Bureau of Indian Standards, which sets and periodically review quality standards (Vipradas 2001).

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 the lower-than-average price of domestic SWH is the robust manufacturing base in India, which is the direct result of an ambitious effort by the

Ministry of Non-conventional Energy Sources (MNES). Moreover, government subsidies in the form of low interest rates help to increase the affordability of the systems for prospective buyers of domestic SWH systems (Vipradas 2001; Press Trust of India 2002; IREDA 2004). Indian SWH buyers would benefit substantially from carbon finance, as up-front costs could be dramatically reduced by selling CERs to bring down costs. For example, with CO_2 prices at $5 per ton and over a seven year crediting period, carbon finance could cover 21% of upfront costs. At the high end, with CO_2 prices at $10 and crediting occurring over a 21-year period, nearly 90% of costs could be covered.

The MNES predicts that the total energy savings due to widespread use of SWH systems in the country's National Capital Region alone would result in a savings of 1,000 MW of power each year (Press Trust of India 2002). Various sources indicate that a typical 100 liter system will yield an annual reduction or roughly 1.5 tons of CO_2 (Kaufman 2003; MNES 2003).

Many of the typical barriers that thwart SWH dissemination in the developing world also apply to the Indian situation. Up-front costs for SWH systems are significantly greater than those for conventional systems; a survey found that only 17% of the sample said they would be willing to buy SWH systems at the prevailing prices. However, many suggested that they would be more likely to buy a system if low-interest loans existed (Reddy 2001). Unfortunately, adequate microcredit opportunities are rare, especially in peri-urban and rural areas. Other problems hinder loan applications in conventional banks. These include ineffective communication between the various bank branches and a general low degree of awareness about SWH among bank officers (ESTIF 2003).

SWH systems also vary greatly in quality, although the MNES and the Bureau of Indian Standards are collaborating to make improvements (ESTIF 2003). Also, an Indian survey found that many respondents lacked confidence in SWH equipment. For example, many had doubts about the savings potential claimed by the manufacturers from the use of SWH systems, believing that the electricity savings potential was fewer than 10%, when in fact it is much greater. Respondents also expressed similar doubts about the life span of SWH systems; the majority perceived it to be less than that of electric water heaters, when in fact they last far longer than any conventional water heating system (Reddy 2001).

The majority of barriers to growth of SWH markets probably fall under the EB's "other" category. The institutional capacity needed for SWH to thrive is lacking. For example, the chain of dealers and installers is not very well organized and is poorly developed. Consequently, the manufacturer is responsible for virtually every step of a SWH system's existence, from research and development, production, and marketing to installation and after-sales service (Vipradas 2001). Also, SWH equipment is not readily available everywhere in India, and the required level of sales, services, and maintenance infrastructure is at a bare minimum, which are additional obstacles for market penetration. SWH retailers are also often unable to offer adequate after-sales and maintenance services, which have been noted as being influential in attracting possible buyers to invest in SWH. There is also a lack of technical capacity to help the industry to design properly sized SWH systems and integrate them with the existing systems and processes (ESTIF 2003).

Mexico:

As of 2000, the vast majority of the 370,000 m^2 of total SWH collector area in Mexico were used by hotels, clubs, and other commercial enterprises to heat swimming pools (CONAE 2002; Buen

2003); households account for only approximately 1% of all SWH installations in Mexico (Davila 2003).

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 Valley metropolitan area consumed natural gas or LPG at the rate of 6 million liters per day (World Bank 1999; Martínez et al. 2001). In much of Mexico, up to half of all gas used by households is for heating hot water (Buen 2003). The federal government keeps energy costs to households low through generous subsidies, and natural gas supplies are widely availability. In 2001, average natural gas prices were 8.7 cents per cubic meter (Martínez, E. 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 are steadily rising, and with water heating services sometimes absorbing up to 50% of a household's energy bill, the market for SWH is slowly growing (Buen 2003; CRE 2004).

In Mexico, as in many other countries, conventional water heating systems are less expensive than their solar thermal counterparts. A 2001 survey of 11 Mexican water heating companies found an average difference between conventional and solar systems of around $270 per system (Martínez, E. et al. 2001), with standard SWH systems for medium-sized households costing roughly $6 per liter of capacity (Davila 2003).

Due to the country's high rate of natural gas use, the effect on the global atmosphere of widespread adoption of SWH technology in Mexico would not be as great as many other countries included in this study. Nevertheless, a survey of existing literature and personal correspondences suggests that

SWH use in Mexico can still be a major contributor to climate protection activities. According to one estimate, SWH systems can reduce daily LPG use in the Mexico City metropolitan area by 21-35%, resulting in an annual abatement of roughly 120,000 to 200,000 tons of Ce per year, or around 0.6 tons of CO_2 per 100 liter system (Martínez, E. et al. 2001). Although LPG burns quite cleanly, widespread SWH use can still improve local air quality, an important consideration in the notoriously smoggy Mexico City region. Nationwide, the rate of carbon savings per square meter of SWH collector area per year could be as high as one ton of CO_2 (Martínez, E. et al. 2001; Davila 2003).

The primary barriers to SWH diffusion in Mexico are related to price and prevailing practice. Not only are equipment costs high, but conventional fuel prices, such as LPG, are kept artificially low. Also, few small-scale financing opportunities exist for SWH purchases, so in the main, only those who can afford pay the entire up-front cost are able to take advantage of the benefits associated with SWH savings (Buen 2003). However, carbon finance could still dramatically reduce the prices of SWH systems: if CO_2 were bought and sold on the market at $10 per ton and were sold over a 14 year period, revenue from CER sales could cover from 15-23% of system costs.

One commentator suggests that the most significant barrier for SWH is low public awareness about the technology. This is primarily a function of low economies of scale of the SWH industry in Mexico, as it does not have the economic capacity to properly market its technology to the general public, for example, reflecting the niche status of SWH in Mexico. Also, even where SWH is popular, there are still plenty of people who have had bad experiences and refuse to accept that the technology has improved. However, collaborative private-public efforts are underway to educate policy makers, consumers, and technicians about SWH (Buen 2003).

The SWH industry in Mexico suffers from a lack of coordination between manufacturers, distributors, retailers, technicians, and users. For example, it is not uncommon for users to have a negative experience with their SWH system because of easily avoided problems such as poor installation, bad orientation or preparation for frost conditions, and little follow-up.

South Africa:

South Africa has a long history of SWH use, though the market has never fully embraced the technology for domestic water heating applications and has instead focused on heaters for swimming pools (Cawood and Morris 2002; Spalding-Fecher, Thorne et al. 2002). The current SWH installed capacity is around 500,000 m^2 (DME 2002), which includes all types. In 2001, South Africans installed approximately 55,000 m^2 and 10,000 m^2 of unglazed and glazed SWHs respectively in residential, commercial and industrial applications.

Electricity prices in South Africa are among the world's lowest, resulting in an artificially skewed preference toward electric water heaters. While electricity tariffs vary widely across the country, the average price was around 3.9 cents in 2000 (WEC 2001; Cawood and Morris 2002; EIA 2004). However, despite having some of the world's cheapest electricity and high rates of electric water heating system adoption, even these are out of reach of the country's poorest (Cawood 2003). Moreover, while the PPP GDP per capita in South Africa is Sub-Saharan Africa's highest by far, income distribution in that country is extremely unequal, with an exceptionally high Gini coefficient of 59.6 (World Bank 2001). Due to this widespread poverty, many households heat water using inefficient electric kettles or electric-, paraffin-, or kerosene- powered stoves (Cawood 2003).

In South Africa, over 90% of electricity is generated by the combustion of coal (UNSD 2004), which South Africa has in abundance (WEC 2001). While relatively low in sulfur (1.2%), South African coal, mostly bituminous, has a high ash content (up to 45%); its enormous role in the country's electricity generation mix is thought to contribute to more than 2,000 cases of fatal respiratory disease in children under five each year (Green Nature 2004).

South Africa produces a wide range of SWH systems, from very basic integral systems that require little plumbing to more elaborate active, split collector systems. Glazed panels are used primarily for residential hot water systems, while unglazed applications in South Africa are limited mainly to heating swimming pools (DME, 2002a). Several firms are experimenting with portable systems that can be manufactured locally and inexpensively, and are durable and easy to use (Nkambule 2000). Many South African systems also have an electric backup system (Cawood and Morris 2002).

Costs of residential SWH systems are on par with the worldwide average, with prices ranging from $5.50 to $9 per liter of capacity (GEF 2001; Borchers and Engel 2002; Spalding-Fecher, Thorne et al. 2002). In South Africa, water heating typically accounts for over 40% of a household's energy use (Spalding-Fecher, Thorne et al. 2002). If domestic SWH systems qualified for CDM financing and could offer CERs on the market, many more households could afford to take advantage of SWH technology. For example, over a 14-year crediting period, 12% of the up-front cost of a system could be covered if CERs could be sold at only $5 per ton, and if CERs were sold at $10 per ton, it could reduce SWH costs by nearly a quarter.

The data for carbon savings related to SWH use in South Africa is quite varied, with estimates ranging from around half a ton of CO_2 per year to over three tons (GEF 2001; Cawood 2003). One of the most reputable actors involved in efforts to install SWH systems in low-income housing, SouthSouthNorth, suggests that the average carbon dioxide abatement for a 100 liter system would be just less than one ton of CO_2 per year (SouthSouthNorth 2004).

A myriad of barriers prevent the South African SWH industry and its advocates from gaining greater levels of penetration. Foremost are those that are financial in nature, as the low cost of electricity ultimately serves to undermine efforts to promote energy conservation or non-electric alternatives to conventional water heating (Van Horen and Simmonds 1998; Spalding-Fecher, Thorne et al. 2002). Moreover, relatively high up-front costs deter many low-income households from using SWH technology, and credit opportunities for SWH purchases are scarce (Spalding-Fecher, Thorne et al. 2002).

The prevailing practices in the South African government, energy utilities, building industries, and other institutions also hamper SWH. For example, the national or regional governments offer very few incentives for people to adapt alternatives to electric water heaters, and in almost every instance, electric water heaters are the default option for all new and retrofitted homes (Spalding-Fecher, Thorne et al. 2002). As a result, the South African SWH industry is weak and fragmented and is unable to attain the economies of scale necessary to firmly control quality and system costs.

Social norms also contribute to the difficulty of promoting SWH. For example, as poor households earn greater income, they typically aspire to emulate the consumption habits of higher-income households, who use electric water heaters. Consequently, energy conservation measures, such as installing SWH systems, are generally considered appropriate only for poor communities (Mehlwana 1997).

Case study analysis

Results of the above case studies and a broader examination of carbon finance yield one overarching conclusion: carbon finance *can* definitely help to overcome barriers to the broader adoption of SWH, including those that are related to investment, technology, prevailing practice, and others. Moreover, there are myriad ways that carbon finance can help to overcome these barriers.

Conventional wisdom suggests that carbon finance will likely never be able to cover the entire cost of renewable energy projects, regardless of their scale, and project developers and consumers will still require other sources of financing to cover the up-front cost of SWH and other renewable energy systems (Pembina Institute 2003; Lundgren 2004). The Prototype Carbon Fund even limits its funding to between 2 and 10% of the total project cost, or a maximum of $5 per ton of CO_2e (Pembina Institute 2003), and one industry participant claims that even if the price of carbon under the CDM reaches levels as high as $15 per ton of CO_2e, the financing it provides for most projects would still likely be more of a "bonus" than a substantial portion of project cost (Lundgren 2004). However, sales of carbon emission reduction credits can greatly reduce the up-front costs that buyers of SWH technology currently incur, and in some cases, carbon finance might even provide over half of the funds needed to purchase the necessary equipment up-front over a SHW system's life span. Especially in areas with high emissions baselines, CER revenue streams could therefore significantly reduce SWH systems costs to consumers, increase the viability and profitability of SWH business activities, or both.

As a way to help overcome investment barriers, a bank or financier may provide partial up-front financing for SWH projects through an Emissions Reductions Purchase Agreement, which is the central legal component of GHG reduction transactions. Besides establishing a framework within which emissions rights are acquired and transferred, ERPAs also serve as a medium through which parties negotiate outcomes that will determine the allocation of risk, which is critical to determining the issue of price and the "bankability" of the project against which to raise further debt, equity, or financing. One specific function of an ERPA is to provide a clause where investors make up-front payments in exchange for promises from the project developers to transfer future carbon savings to the investor. The value of the up-front investment is usually a function of the net present value of future carbon emission reductions (Ibay 2002; Lundgren 2004). Another option for investors is to provide partial financing for a CDM project in the form of a loan to the project developers. In such cases, the loan principal would be repaid over an agreed upon period, with a return in the form of CERs rather than a financial return.

On the promise of future carbon revenues alone, most lending agencies will be unlikely to lend financial support for development of SSC renewable energy projects. Even with purchase guarantees by buyers of carbon, the risk associated with developing a clean energy project in LDCs may still be too great. However, depending on how the two parties design an ERPA, the risk of a project's non-performance could be managed so that all parties accept the risk allocation. For example, an investor might choose to assume all of the risk of a failed project if the potential return to his investment is high enough. All parties could share risk by purchasing venture insurance, or project developers might entirely accept the risk, under the condition that the buyer pay more per ton of avoided emissions.

Beyond reducing the up-front cost of SWH systems, carbon finance can help overcome other barriers to the development of SWH markets. Unless an ERPA stipulates otherwise, carbon revenue earned by governments – or any entity for that matter – should be able to fund virtually anything contributing to the removal of barriers. In this context, at least in theory, carbon revenue can fund any SWH promotion activities that help 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, all of which are among the barriers that can be used to demonstrate "additionality" for SSC CDM projects. To obtain CDM approval, project participants would need to define the barrier removal activities they will conduct 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.

To overcome technology barriers, carbon finance can be beneficial by helping to fund efforts to improve SWH equipment standards and testing regimes. Carbon revenue can help develop standard codes of practice for all stages of SWH installation, from initial setup to regular monitoring of SWH operations. Activities that strengthen the technical, institutional and human capacity of technology providers through training and other educational methods, such as study tours, could also potentially be funded through carbon finance.

To address barriers that stem from the prevailing use of conventional water heaters, such as a lack of familiarity with SWH 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 the costs and benefits of SWH versus conventional systems. Demonstrations of high quality systems could also reinforce claims that SWH can be reliable and provide substantial reductions in fuel cost.

Carbon finance can also help build capacity among the private sector, government, project developers, and NGOs. SWH development initiatives at national, regional, or local levels could oversee various efforts. Collaborative relationships between the above sectors can yield long-term improvements in the institutional capacity necessary to make the linkages from SWH import or production to wide-scale diffusion. Carbon finance could fund the training of decision-makers, home builders, technicians, end-users, and others. For example, financial officers could receive training to help them better assess the long-term economic value of installed SWH technology. If project details can be worked out among participants, these sorts of capacity building activities could be an ideal application of carbon finance.

VII. Conclusion

Climate change is one of the most challenging environmental threats with which humanity has to cope. Countries everywhere will have to face the tragic environmental, economic, and social consequences if concerted collective action is not taken immediately to address this issue. Furthermore, in a sick twist of fate, by virtue of their geographic locations and weak adaptive capabilities, some of the world's poorest countries are apt to be the most profoundly affected by these changes in the Earth's climate. Therefore, it is essential that an international legally binding document like the Kyoto Protocol includes an instrument designed to meet the needs of these extraordinarily vulnerable countries and not merely those of industrialized countries. It is equally important that a universally accepted mechanism to transfer funds from the North to the South exists. As demonstrated above, the Clean Development Mechanism offers a good place to start.

Carbon finance through the CDM can provide much-needed resources to the world's developing countries while contributing to global GHG mitigation efforts. There are myriad technologies that carbon finance can help advance; and among the most promising from both carbon protection and sustainable development perspectives is that of the solar water heater. Using carbon finance to engage in additional measures to support SWH dissemination can contribute to economic and social development and environmental protection throughout the developing world, playing a small but important role in the worldwide struggle for sustainable development.

While revenue earned by the sale of carbon credits can make some projects more financially attractive and tip a project's balance toward financial viability, carbon finance is not a panacea for SWH or renewable energy projects in general. However, by stimulating worldwide demand for carbon emission reductions credits, the CDM can provide an important boost to clean energy technology markets. Moreover, with added incentives to drive revenue to some of the LDCs where modern energy services are all but lacking, carbon markets have the potential to make an enormous impact on the lives of people all over the world.

Bibliography

Ackerman, Frank and William Moomaw (1997). "SO2 emissions trading: does it work?" The Electricity Journal **10**(7): 61-66.

Acra, A., Z. Raffoul, et al. (1984). Solar Disinfection of Drinking Water and Oral Rehydration Solutions - Guidelines for Household Application in Developing Countries, UNICEF, American University of Beirut.

Agarwal, Anil (2000). Making the Kyoto Protocol work: Ecological and economic effectiveness, and equity in the climate regime. New Delhi, Centre for Science and Environment (CSE).

Agarwal, Anil, Sunita Narain, et al. (1999). Green Politics. New Delhi, Centre for Science and Environment (CSE).

Anonymous (1990). "No Agreement on CO2 Reduction Targets." Environmental Policy and Law **20**(6): 196-199.

Austin, Duncan and Paul Faeth (1999). How much sustainable development can we expect from the Clean Development Mechanism? Climate Notes **November**.

Austin, Greg, Anthony Williams, et al. (2003). Employment Potential of Renewable Energy in South Africa. Constantia, South Africa, AGAMA Energy (Pty) Ltd**:** 104.

Balachandran, Anand (2002). Diffusing Clean Technologies in Rural India - An Evaluation of the Government's Programs. The Fletcher School of Law and Diplomacy. Medford, Tufts University.

Balce, Guillermo R. (2001). Local Manufacturing Capability in Energy of ASEAN Countries. ASEAN energy bulletin **5** (3).

Borchers, Mark and Wendy Engel (2002). "Solar water heaters - the way forward?" ESI Africa **1 2002**.

Brockett, Debbie, David Fridley, et al. (2002). A Tale of Five Cities: The China Residential Energy Consumption Survey. Berkeley, Lawrence Berkeley National Laboratory.

Buen, Odón de (2003). "¿Por qué en México los Calentadores Solares no son tan comunes como deberían?" Agua y Desarrollo Sustenable **1**(6).

Butti, Ken and John Perlin (1980). A Golden Thread. Palo Alto, Cheshire Books.

Cawood, Will (2003). eThekwini solar water heating project: progress report. SESSA Friend **December**.

Cawood, Will and Glynn Morris (2002). Baseline study - solar energy in South Africa. Pretoria, Government of South Africa: Department of Minerals and Energy.

CDM Watch (2003). The Clean Development Mechanism (CDM) Toolkit: A resource for stakeholders, activists and NGOs. Denpasar, Indonesia, CDM Watch.

Changzhou Skypower Solar Industry Co. Ltd (2003). Luxury products packaging and price list, Changzhou Skypower Solar Energy Industry Co.,Ltd.

Chidumayo, Emmanuel N. (1997). "Woodfuel and Deforestation in Southern Africa - a misconceived association." Renewable Energy for Development **10**(2).

Ciochetti, D.A. and R.H. Metcalf (1984). "Pasteurization of naturally contaminated water with solar energy." Applied & Environmental Microbiology **47**(2): 223-228.

Clancy, Joy (2003). Gender and Household Energy - the international context. Enschede, the Netherlands, Technology and Development Group, University of Twente.

CONAE (2002). Aplicación de Sistemas Solares de Calentamiento de Agua en Casas Habitación. México, La Comisión Nacional para el Ahorro de Energía.

CRE (2004). Estadicas básicas de los mercados de gas y electricidad en México, así como de termas relativos a la CRE: GLP - ventas de primera mano, Comision Reguladora de Energia.

CRID (2003). Lettre ouverte des ONG françaises sur l'observatoire MDP, Centre de Recherche et d'Information pour le Developpement.

Davidson, Ogunlade and Youba Sokona (2002). A new sustainable energy path for African development: Think bigger act faster. Cape Town, South Africa and Dakar, Senegal, Energy and Development Research Centre and Environmental Development Action in the Third World.

Davila, Jorge (2003). Email regarding Sunway de México's solar water heating products. S. Kaufman. México D.F.

DBSA (1999). Assessing the Integrated Regional Potential for the Widespread Introduction and Application of Appropriate Renewable Energy Technologies Within SADC. Midrand, South Africa, International Solar Energy Society (ISES) and the Development Bank of Southern Africa (DBSA).

DME (2002). Draft White Paper on Renewable Energy and Clean Energy Development. Pretoria, Department of Minerals and Energy.

Doyle, Alister (2003). Kyoto Fate Unclear as UN Climate Talks End. **Reuters News Service**, (December 16).

Ecocity (2000). R1,8 million boost for Midrand EcoCity. **EcoCity Newsletter**, Johannesburg.

EIA (2004). Electricity Prices for Households, United States Energy Information Agency. **2004**.

ENB (1998). Daily Web Coverage, COP-4, International Institute for Sustainable Development (IISD).

ENB (2000). Daily Web Coverage, COP-6, International Institute for Sustainable Development (IISD).

ENB (2002). Daily Web Coverage, COP-8, International Institute for Sustainable Development (IISD).

EPA (2003). Clean Air Markets website, United States Environmental Protection Agency. **2003**.

ESOK (2000). Energy Management for a Sustainable Tourism Industry in Kenya. Nairobi, Ecotourism Society of Kenya.

ESTIF (2003). Sun in Action II –A Solar Thermal Strategy for Europe. Volume 1: Market Overview, Perspectives and Strategy for Growth. Brussels, European Solar Thermal Industry Federation.

ESTIF (2003). Sun in Action II –A Solar Thermal Strategy for Europe. Volume 2: The Solar Thermal Sector Country by Country. Brussels, European Solar Thermal Industry Federation.

Fankhauser, S (1995). Valuing Climate Change: The Economics of the Greenhouse. London, Earthscan.

GEF (1999). Project Brief: Morocco Market Development for Solar Water Heaters. Washington, DC, Global Environment Facility.

GEF (2001). Project Summary: Solar water heaters (SWHs) for low-income housing in peri-urban areas in South Africa. Washington, DC, Global Environment Facility.

GEF (2002). Project Document: Barrier Removal to Namibian Renewable Energy Programme. Washington, DC, Global Environment Facility.

Goldemberg, José (1996). Energy, Environment and Development. London, Earthscan.

Government of Barbados (1999). Intervention of the Delegation of Barbados to Commission III of the 30th Session of the UNESCO'S General Conference. Paris, UNESCO.

Government of Barbados (2001). The National Communication to the UNFCCC. St. Michael, Barbados, Ministry of Physical Development and Environment.

Graham, James (2001). “Ripening RE markets: capacity building for the rapid commercialisation of RE in China.” RE-Focus **April**: 18-23.

Grameen Bank (2003). Grameen Shakti: Development of Renewable Energy Resources for Poverty Allevition, Grameen Bank. **2003**.

Green Nature (2004). Energy and the Environment in South Africa, Green Nature.

Guiney, William T. (2002). What's new in 2002 for Solar Water Heating? **SolarAccess.com**.

Hasselknippe, Henrik (2003). "Systems for carbon trading: an overview." Climate Policy **3**(Supplement 2): S43-S57.

Hedger, Merylyn McKenzie, Eric Martinot, et al. (2001). Enabling Environments for Technology Transfer. Methodological and Technological Issues in Technology Transfer: A Special Report of IPCC Working Group III. B. Metz, O. Davidson and J.-W. Martens. Cambridge, Cambridge University Press.

Humphreys, Stephen, Youba Sokona, et al. (1998). Equity in the CDM. The E7 Observer **19, Buenos Aires Special Issue**.

Ibay, Angela Consuelo S. (2002). Legal Aspects of the Emission Reduction Purchase Agreement. Manila, Climate Change Information Center.

IEA (2001). International Emission Trading: From Concept to Reality. Paris, International Energy Agency.

IEA (2002). Electricity in India. Paris, International Energy Agency.

IFS On-Line (2004). Market Prices and Unit Values, 2001, International Monetary Fund. **2004**.

Ince, David (2000). Development of Solar Water Heating and other Renewable Energy Technologies in Barbados. Bridgetown, Ministry of Environment, Energy and Natural Resources.

IndiaSolar.com (2003). Solar Water Heating Systems, IndiaSolar.com. **2003**.

Interlaboratory Working Group (1997). Scenarios of US Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond. Oak Ridge, TN and Berkeley, CA, Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory.

Interlaboratory Working Group (2000). Scenarios for a Clean Energy Future. Oak Ridge, TN and Berkeley, CA, Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory.

IPCC (2001). Climate Change 2001: Impacts, Adaptation & Vulnerability. Sixth Session of IPCC (Intergovernmental Panel on Climate Change) Working Group II, Geneva, Cambridge University Press.

IPCC (2001). Climate Change 2001: Mitigation. Sixth Session of IPCC Working Group III, Geneva, Cambridge University Press.

IPCC (2001). Climate Change 2001: The Scientific Basis. Sixth Session of IPCC (Intergovernmental Panel on Climate Change) Working Group I, Geneva, Cambridge University Press.

IPCC-NGGIP (1997). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Workbook (Volume 2). Geneva, Intergovernmental Panel on Climate Change - National Greenhouse Gas Inventories Programme.

IPMVP (2003). Concepts and Options for Determining Energy Savings. Washington, DC, International Performance Measurement and Verification Protocol.

IREDA (2004). Sectors Financed: Solar Thermal Programme, Indian Renewable Energy Development Agency Limited. **2004**.

ITDG (2004). Technical brief: soapmaking. Bourton-on-Dunsmore, UK, Intermediate Technology Development Group.

Jaura, Ramesh (2002). GLOBAL WARMING: NGOs Concerned About Fate Of Kyoto Treaty. **Inter Press Service**, (December 11).

Jensen, Thomas Lynge (2000). Renewable Energy on Small Islands, Second Edition. Copenhagen, Forum for Energy and Development.

Joyce, T. M., K.G. McGuigan, et al. (1996). "Inactivation of fecal bacteria in drinking water by solar heating." Applied & Environmental Microbiology **62**(2): 399-402.

Junfeng, Li (2003). Renewable Energy Policies & Market in China. Beijing, Chinese Renewable Energy Industries Association.

Kamal, Sajed (2004). Personal communication. S. Milton. Cambridge.

Karekezi, Stephen (2002). The Case for De-Emphasizing PV in Renewable Energy Strategies for Rural Africa. Nairobi, African Energy Policy Research Network/Foundation for Woodstove Dissemination.

Kaufman, Steven (2003). Personal communication. S. Milton. Arlington.

Knox, Angie (2002). Sinking feeling in Tuvalu. **BBC**, London (Wednesday, 28 August).

Lazarus, Michael, Sivan Kartha, et al. (2000). Key Issues in Benchmark Baselines for the CDM: Aggregation, Stringency, Cohorts, and Updating. Boston, Tellus Institute.

Lecocq, Franck and Karan Capoor (2002). State and Trends of the Carbon Market. Washington, DC, World Bank.

Li Hua (2002). China's solar thermal industry: Threat or opportunity for European companies? Renewable Energy World **July-August**.

Logan, Jeffrey and Luo Dongkun (1999). Natural Gas and China's Environment. Richland, Washington, Pacific Northwest National Laboratory.

Logan, Jeffrey and Dong Xiucheng (2002). Expanding Natural Gas Use in China. Pacific Northwest National Laboratory, Richland, Washington.

Lundgren, Annika (2004). Personal communication. S. Milton.

Maegaard, Preben (2003). From Fossil Fuels to the Energy Solutions of the Future. The SWH (Solar, Wind, Hydrogen and Fuel Cells) International Conference, Segovia, Spain.

Martínez, Juan Quintanilla, Mariano Bauer E., et al. (2001). Uso Masivo de la energía solar en sustitución de combustibles fósiles en la Zona Metropolitana del Valle de México: Sectores residencial, hospitalario, hotelero, y de baños públicos. México DF, Programa Universitario de Energía, UNAM.

Matibe, Khorommbi (1999). Social monitoring guidelines for flexible mechanism projects under the United Nations Framework Convention on Climate Change in South Africa. Cape Town, Energy and Development Research Centre.

McDiarmid, Derrick (1999). Solar water heating: an economic option for utilities. Harare, Solamatics and R. McDiarmid & Co.Ltd.

McKibbin, Warwick J. (1998). International Permit Trading: Creating a Sustainable System. Sydney, Research School of Pacific and Asian Studies.

Mehlwana, Anthony Mongameli (1997). "The Anthropology of fuels: situational analysis and energy use in urban lowincome townships of South Africa." Energy for Sustainable Development - The Journal of the International Energy Initiative **3**(5).

Michaelowa, Axel, Marcus Stronzik, et al. (2003). "Transaction costs of the Kyoto Mechanisms." Climate Policy **3**: 261-278.

Millock, Katrin (2002). "Technology transfers in the Clean Development Mechanism: an incentives issue." Environment and Development Economics **7**: 449-466.

Mirasgedis, S., D. Diakoulaki, et al. (1996). "Solar energy and the abatement of atmospheric emissions." Renewable Energy **7**(4): 329-338.

MNES (2003). Soft Loan Programme on Solar Water Heaters, Ministry of Non-Conventional Energy Sources (India). **2004**.

MNES (2004). Baselines for Renewable Energy Projects under Clean Development Mechanism. New Delhi, Ministry of Non-Conventional Energy Sources (India).

MoFAoJ (1995). FINESSE Activities in the SADC Region. Tokyo, Ministry for Foreign Affairs of Japan.

Morrison, Graham (2002). "Technology Update: Solar water systems - design and performance." Renewable Energy World **5**(2).

Nadel, Steven, Leo Rainer, et al. (1998). Emerging Energy-Savings Technologies and Practices for the Buildings Sector. Washington, DC, American Council for an Energy-Efficient Economy.

NAHB Research Center Inc. (1998). Opportunities for Solar Water Heating. Golden, CO, National Renewable Energy Laboratory.

Nkambule, Ketlametswe (2000). Consumer response to mobile solar water heating in the low-income sector, South Africa. Boiling Point **45**.

OPET-TERI and HECOPET (2002). Status of Solar Thermal Technologies and Markets in India and Europe. New Delhi, Organisations for the Promotion of (clean and efficient) Energy Technologies.

Orawo, Peter, Ed. (2001). Private Sector, Sustainable Development in Africa: What Opportunities in CDM? IMPACT, Climate Network Africa.

PCF*plus* (2002). Executive Summary: State of the Carbon Market. Washington, PCF plus Research team.

Pembina Institute (2003). A User's Guide to the CDM (Clean Development Mechanism): Second Edition. Drayton Valley, Canada, The Pembina Institute.

Piyasvasti, Amranand (2001). Boost of Local Manufacturing of New Energy Systems and Energy Efficient Products in Thailand. ASEAN energy bulletin **5** (3).

Point Carbon (2002). Key Indicators. **November 20**.

Point Carbon (2003). Market comment. Carbon Market Europe **December 19**.

Point Carbon (2003). Taking the proactive approach: Costa Rica. CDM Monitor **November 6**.

Point Carbon (2004). Carbon Market Indicator. **March 5**.

Point Carbon (2004). IETA's Trading Scheme Database, International Emissions Trading Association. **2004**.

Point Carbon (2004). Validators' Venue: Additionality criterion cripples CDM. CDM Monitor **March 11**.

Press Trust of India (2002). Solar water heaters can help tide over power shortages. **The Press Trust of India**, (October 25).

PRESSEA (2003). Solar Thermal - Barriers / Social and Cultural Issues, ASEAN Centre for Energy. **2003**.

Pronove, Gao (2002). The Kyoto Protocol and the Emerging Carbon Market. Geneva, UNCTAD/Earth Council Carbon Market Programme.

Reddy, Amulya K.N. (2002). Energy Technologies and Policies for Rural Development. Energy for Sustainable Development: A Policy Agenda. New York, United Nations Development Programme (UNDP).

Reddy, B.S. (2001). Barriers to the Diffusion of Renewable Energy Technologies - A Case Study of the State of Maharashtra, India. Roskilde, UNEP Collaborating Centre on Energy and Environment.

RETScreen International (2001). Solar Water Heating Project Analysis, Natural Resources Canada.

Samaniego, Joséluis and Christiana Figueres (2002). Evolving to a sector-based Clean Development Mechanism. Building on the Kyoto Protocol: Options for protecting the environment. K. A. Baumert, O. Blanchard, S. Llosa and J. F. Perkaus. Washington, DC, World Resources Institute.

Schaffner, Julie (2002). Class notes. Micro Development Economics: Poverty Reduction Policy Analysis for Developing Countries (EIB-E241), The Fletcher School of Law and Diplomacy.

SIDSnet (2000). Extensive Use of Solar Water Heaters in Cyprus. New York, Small Island Developing States Network.

Sinha, Chandra Shekhar, Shirish Sinha, et al. (1998). "Energy use in the rural areas of India: setting up a rural energy data base." Biomass and Bioenergy **14**(5-6): 489-503.

Sinton, Jonathan E. and David G. Fridley (2001). Hot Air and Cold Water: The unexpected fall in China's energy use. China Environment Series. Washington, DC, Woodrow Wilson Center.

Sokona, Youba (2004). Personal interview. S. Milton.

Sokona, Youba, Stephen Humphreys, et al. (1997). The Clean Development Mechanism: What Prospects for Africa? Dakar, Energy Programme, ENDA- TM.

Sokona, Youba, Stephen Humphreys, et al. (1998). Sustainable Development: A Centrepiece of the Kyoto Protocol: An African perspective. Fourth Conference of the Parties to the United Nations Framework Convention on Climate Change, Buenos Aires, Stockholm Environment Institute.

Sokona, Youba and Djimingué Nanasta (2000). The Clean Development Mechanism: An African Delusion? Dakar, ENDA-TM.

Solarbuzz (2002). Solar heaters to help trim power bills, Reuters.

SouthSouthNorth (2004). South Africa: Low-cost urban housing upgrade: Khayelitsha (Cape Town). Summary of CDM project activity. Cape Town, SouthSouthNorth.

Spalding-Fecher, Randall, Ed. (2002). The CDM guidebook: A resource for clean development mechanism project developers in Southern Africa. Cape Town, Energy and Development Research Center (EDRC).

Spalding-Fecher, Randall, Steve Thorne, et al. (2002). "Residential Solar Water Heating as a Potential Clean Development Mechanism Project: A South African Case Study." Mitigation and Adaptation Strategies for Global Change **7**: 135-153.

Srivastava, L. and P. Soni (1998). Financing options for protecting the climate. Climate Change: Post-Kyoto Perspectives from the South. New Delhi, Tata Energy Research Institute (TERI).

Sunpower Hot Water Systems (2004). Sunpower website.

TERI (2002). Community Development Carbon Fund: Development + Carbon + Carbon with a human face. New Delhi, The Energy and Resources Institute.

UN (1992). Agenda 21. New York, United Nations.

UNDESA (1999). Capacity-building for rapid commercialisation of renewable energy. New York, UN Department of Economic and Social Affairs.

UNDP (2002). Capacity 21 Case Studies: A Catalyst for Sustainable Energy Policies and Strategies. New York.

UNDP (2003). Human Development Report 2003. New York, United Nations Development Programme.

UNEP (2003). Enterprise Investment Summary. The REED Report, United Nations Environment Programme. **September 2003**.

UNFCCC (1997). Kyoto Protocol to the United Nations Convention on Climate Change. New York, United Nations.

UNFCCC (2002). First Report of the Executive Board of the
Clean Development Mechanism (2001-2002). New York, United Nations.

UNFCCC (2002). Report of The Conference of the Parties on Its Seventh Session, Held at Marrakesh from 29 October to 10 November 2001. New York, United Nations.

UNFCCC (2003). Report of the Seventh Meeting of the Executive Board: Annex 6, Appendix B (Indicative Simplified Baseline and Monitoring Methodologies for Selected Small-Scale CDM Project Activity Categories). New York, United Nations.

UNFCCC (2004). Approved baseline methodology AM0004: Grid-connected Biomass Power Generation that avoids Uncontrolled Burning of Biomass. New York, United Nations.

UN-HABITAT (1999). Barbados. Nairobi, United Nations Human Settlements Programme. **2004**.

UN-HABITAT (2003). Water and Sanitation in the World's Cities. London, Earthscan.

UNSD (2004). 1998 Energy Balances and Electricity Profiles, United Nations Statistics Division. **2004**.

US Embassy Beijing (1998). Hot Water For China -- A PRC Solar Water Heater Company. Beijing, United States Embassy Beijing.

Van Horen, Clive and Gillian Simmonds (1998). "Energy efficiency and social equity in South Africa: Seeking convergence." Energy Policy **26**(11): 893-903.

Varughese, George C. (2004). Personal interview. S. Milton.

Vipradas, Mahesh (2001). "Solar thermal technology: the Indian scenario." Energy Technology News **4,5**.

VROM (2001). Standardised Baselines and Streamlined Monitoring Procedures for Selected Smallscale Clean Development Mechanism Project Activities. Den Haag, Ministry of Housing, Spatial Planning and the Environment of the Netherlands.

WEC (2001). Pricing Energy in Developing Countries. London, World Energy Council.

Weiss, Werner and Norbert Demmelbauer (1997). Sustainable development from solar energy. Erneuerbare Energie **1/97**.

World Bank (1999). Plan de acción para ciudad de méxico, Iniciativa de Aire Limpio en las Ciudades de América Latina. **2004**.

World Bank (2001). World Development Report 2000/2001: Attacking Poverty. Washington, The World Bank.

World Bank (2003). CDCF Overview Document. Washington, DC, World Bank.

World Bank (2003). Small Scale CDM Projects: An Overview. Washington, DC, The World Bank.

World Bank (2003). Supporting Poor Communities Under the Kyoto Protocol: New Community Carbon Fund Launched (Press Release).

World Bank (2004). Barbados Country Brief. Washington, DC, World Bank.

Xiao, Chaofeng, Huilong Luo, et al. (2004). "Solar thermal utilization in China." Renewable Energy **Article in Press**.

Yergin, Daniel (1993). The Prize: The Epic Quest for Oil, Money, and Power. New York, Touchstone Books.