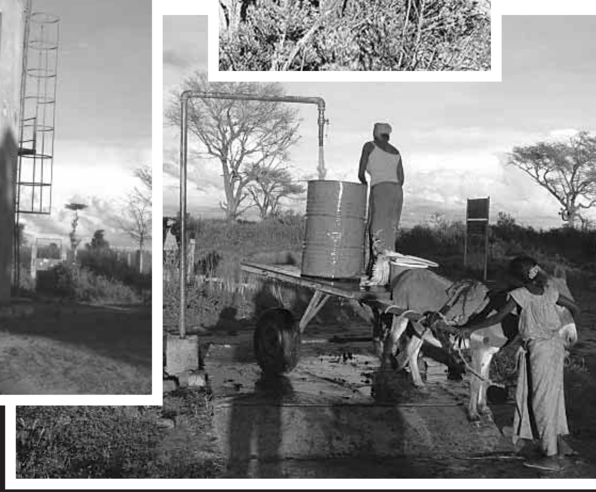
Seeing the Light

Adapting to climate change with decentralized renewable energy in developing countries



Edited by
Henry David Venema
and Moussa Cisse

Climate Change Knowledge Network

iisd International Institute for Sustainable Development
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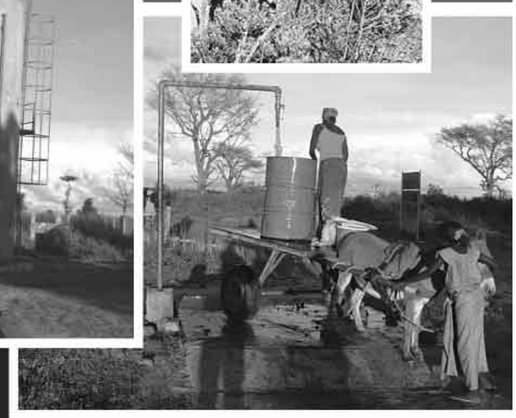


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About the CCKN

The Climate Change Knowledge Network (CCKN) came together in 1998 to open and increase the exchange of knowledge and research expertise between developed and developing countries on climate change-related activities and to make this knowledge accessible throughout the world. Through the cross fertilization of ideas and collaborative efforts within the network, the CCKN strives to strengthen the pool of knowledge on climate change that can inform the international policy process on this issue.

Collectively the member organizations of the CCKN seek to:

- promote a more effective, sustainable and equitable climate change regime through capacity building, research and communication on issues such as the Kyoto mechanisms, adaptation and technology transfer;
- improve dialogue and exchange among industrialized and developing countries in an effort to enhance understanding of the linkages between climate change and sustainable development in all regions; and
- develop the capacity of its own member organizations to create and communicate policy-relevant, country- and region-specific knowledge on climate change.

The CCKN puts a particular emphasis on using its unique combination of substantive, technical and geographic expertise and perspectives to build the capacity of developing countries to respond to climate change in a manner consistent with their own sustainable development priorities.

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Preface

In the pages that follow, *Seeing the Light: Adapting to climate change with decentralized renewable energy in developing countries* explores the role that decentralized renewable energy (DRE) projects play as a mitigative and adaptive response to climate change. *Seeing the Light* examines the rationale for developing DRE projects (or DREs) as a mitigation and adaptation response to climate change; presents the DRE experience in five developing countries; and examines the conditions under which the same countries can support and promote DRE through the existing Clean Development Mechanism under the Kyoto Protocol. The book concludes with policy recommendations for more vigorous DRE support within the existing protocol and beyond the Kyoto era.

The Delhi Declaration, issued at the conclusion of the Eighth Conference of the Parties (COP-8) to the United Nations Framework Convention on Climate Change (UNFCCC), provides a useful entry point into understanding the role DREs can play in linking mitigation and adaptation issues within climate policy. The Delhi Declaration acknowledges that "significant cuts in global emissions will be necessary" to meet the Convention objective of stabilizing atmospheric greenhouse gas (GHG) concentrations, but also reaffirms that "economic and social development and poverty eradication are the first and overriding priorities of developing country partners" (UNFCCC, 2002). The Delhi Declaration highlights two development issues particularly relevant to climate policy, reflecting recent insights from the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report and the World Summit on Sustainable Development (WSSD) Plan of Implementation: vulnerability to climate change increases with the level of under-development; and energy deprivation exacerbates under-development.

Essentially, the Delhi Declaration expresses the realpolitik of climate policy—the South remains uninterested in mitigating emissions decontextualized from a broader sustainable development agenda that addresses their high vulnerability to climate change, and the need to increase energy consumption for basic development. Rather than an impasse to coherent policy, however, the Delhi Declaration opportunes a re-invigorated approach to climate change based on fundamental sustainable development principles, which reflect, in fact, mitigation-adaptation synergies and are intrinsic to the ecosystem-oriented poverty alleviation priorities counselled by the WSSD plan.

The IPCC synthesis concluded that the least developed countries are the least endowed with adaptive capacity and hence most vulnerable to climate change. Climate stresses in the most vulnerable communities exacerbate population, resource depletion and poverty pressures—the more extreme the climate change scenario, the greater the disparity between developed and developing countries. The IPCC also concluded that climate adaptation, sustainable development and improved equity can all be mutually reinforcing if policies are advanced which lessen resource pressure, improve environmental risk management and increase welfare for the poorest members of society (IPCC, 2001a, p. 7).

Simultaneously, the World Summit on Sustainable Development Plan of Implementation asserts the primacy of the ecosystem-level determinants of sustainable development and poverty alleviation, known as the water, energy, health, agriculture and biodiversity (WEHAB) agenda. Moreover, energy provisioning is understood with much greater clarity within the WSSD plan as a necessary pre-condition for poverty alleviation and sustainable development. The WSSD plan also proposes decentralized renewable energy as a key delivery mechanism for improving energy services delivery to impoverished regions of the developing world. *Seeing the Light* explores this role for DRE as a fundamental sustainable development priority and as an example of a mitigation-adaptation synergy that provides a constructive focus for integrative rather than divisive international climate policy.

Seeing the Light is divided into two major sections. Part I is devoted to developing a new conceptual model for DRE as an example of mitigation-adaptation synergies, and then reviews the DRE experience of five developing countries. Part II examines the Clean Development Mechanism as a key financial instrument for supporting decentralized renewable energy.

Chapter 1 of Part I puts forward a general conceptual framework that illustrates how introducing modern energy services through decentralized renewable energy can stabilize the ecological and social determinants of climate change vulnerability, while performing a critical climate change mitigation function. Chapter 1 begins with a high-level overview of the key implications of rural energy deprivation: deforestation and ecosystem degradation (with significant greenhouse gas emissions implications), chronic rural poverty and high vulnerability to the negative impacts of climate change. Chapter 1 then explores global sustainable development pathways and the integral role that decentralized renewable energy could play in stabilizing greenhouse gas concentrations in the atmosphere at levels that would prevent dangerous anthropogenic interference with the climate system. We then describe how mitigation and adaptation synergies provide avenues for integrating sustainable development with climate policy, contextualized with respect to key relationships between the Millennium Development Goals and access to energy. We then turn to the related issue of poverty and climate change in the context of how climate stresses exacerbate poverty by impairing the ecosystem services upon which the poor rely heavily. Chapter 1 concludes with a full description of the role DREs play in rural agroecosystems, particularly how DREs can enhance the flow of regulatory and provisioning ecosystem services, and expand livelihood opportunities—all of which builds adaptive capacity for climate change.

Chapters 2–6 comprise case studies on the DRE experience in each of five developing countries. Each country study illustrates some or many of the key mitigation-adaptation linkages introduced in Chapter 1.

The Bariloche Foundation contributes a rural electrification case study from Jujuy province in Argentina that illustrates how the introduction of household electricity can mitigate greenhouse gas emissions, improve livelihoods and create social opportunities, all of which builds the adaptive capacity of rural communities. The Bangladesh University of Engineering and Technology contributes two case studies, both highlighting the linkages between small-scale modern biomass energy services and improved ecosystem management as simultaneous climate change mitigation and adaptation strategies.

The International Virtual Institute of Global Change contributes a case study from Brazil that also highlights the bioenergy-ecosystem services linkage. In this case, deforested tracts of northwestern Amazonia, highly vulnerable to further degradation from climate change, are targeted for bioenergy feedstock production to supply electricity in two rural communities. The project involves a fuel switch from diesel to biodiesel and has the potential to generate income and create jobs while simultaneously reducing carbon emissions.

Environnement et développement du tiers-monde (ENDA) contributes two case studies from Senegal. The first describes a rural solar photovoltaic electrification project that improves water and electricity supplies, and increases resilience to drought stresses. The second case study, illustrates the mitigation-adaptation synergies of an intensified agroforestry system pioneered in Senegal.

The Southern Centre for Energy and Environment contributes a case study from Zimbabwe that illustrates the potential of wind-based water pumping as a critical climate change adaptation strategy for agriculture, and the potential for the CDM to support appropriate technology transfer. Here, small-scale wind turbine generators have been adapted to local needs, successfully disseminated, and maintained by locally-trained staff.

Part I concludes with Chapter 7, a synthesis of the preceding chapters.

Part II of the book begins with Chapter 8, a review of the CDM, the key instrument under the Kyoto Protocol for North-South cooperation in supporting climate change mitigation activities—including DRE projects—in the developing world. This introduction to the CDM provides a brief review of the history, modalities and current status of the CDM, including the rationale and the status of the "fast-track" modalities for small-scale energy projects, including DREs.

Chapters 9–13 review country-level experience with the CDM and its predecessor instrument, Activities Implemented Jointly (AIJ), in Argentina, Bangladesh, Brazil, Senegal and Zimbabwe. The country studies also discuss the current status of the Designated National Authority (DNA) for the CDM in each of the five countries, and the potential for including the climate change adaptation potential of DRE projects into country-level CDM planning activities.

The key findings of this review of country-level CDM activities include the following.

In Argentina, the technical capacity exists to develop high-quality DRE projects with local livelihood benefits, however this expertise is not well-integrated into the CDM Designated National Authority. Furthermore, climate change adaptation work in general is neglected.

In Bangladesh, the NGO movement in rural areas has been extremely successful in promoting DRE projects. To extend and expand their activities many are looking into DRE projects, but very little technical support is available to them. However, the CDM is by and large an unknown concept among the DRE project proponents even if, at the same time, Bangladesh is probably the best example among the five countries covered of integrating adaptation and mitigation expertise within their DNA. It should be pointed out, however that there is no representation from the ministry in charge of DREs within the DNA and no specific recognition of mitigation-adaptation linkages.

The Brazilian case indicates that various CDM project activities and types are currently underway in the country at different stages. DREs are prominent among these project activities as a high potential for developing CDM projects does exist in various sectors of the Brazilian economy, particularly in the energy and industrial sectors. Because expertise in CDM-related activities is held by a relatively small group of government and university officials, there is an urgent need for broader CDM capacity building in Brazil.

In Senegal decentralized renewable energy has always been recognized as a credible alternative in strategies aimed at providing local populations with access to alternative energy sources while preserving the environment. Senegal has the institutional capacity and sufficient expertise to formulate DRE projects from a development perspective. However, there is limited capacity for CDM and adaptation projects due to the lack of experience in these kind of projects and climate change policy. CDM and adaptation are fairly unknown concepts among the promoters of DRE technologies. Currently, the climate change focal point and the National Committee have very limited capability to promote the activities under CDM and adaptation. The industrial sector as well as local communities have not been very responsive to climate change issues due to a lack of information. The case study of Zimbabwe indicates that the technical capacity exists within Zimbabwe to develop CDM approval criteria consistent with sustainable development principles and the mitigation-adaptation opportunities of DRE, but the capacity to actually administer the CDM within Zimbabwe remains weak. Indeed, there is still no institutional framework to aid the national CDM process.

Although significant differences exist with respect to capability of hosting CDM projects in the countries surveyed, we observe that, in general, an enormous amount of DNA capacity-building remains to be done. The need for comprehensive capacity-building in climate issues is even greater if the sustainable development potential of DREs—particularly the agroecosystem-level synergy between mitigation and adaptation—is to be realized.

Chapter 14 concludes the book with some reflections on the role of DRE within the current Kyoto Protocol—and within a larger sustainable development context—as an example of integrative climate policy. We then provide several key policy recommendations for more vigorous DRE support within the current climate regime, and looking forward to its evolution.

Table of Contents

Preface iii

Part I:
Linking Mitigation and Adaptation Through Energy Access 1

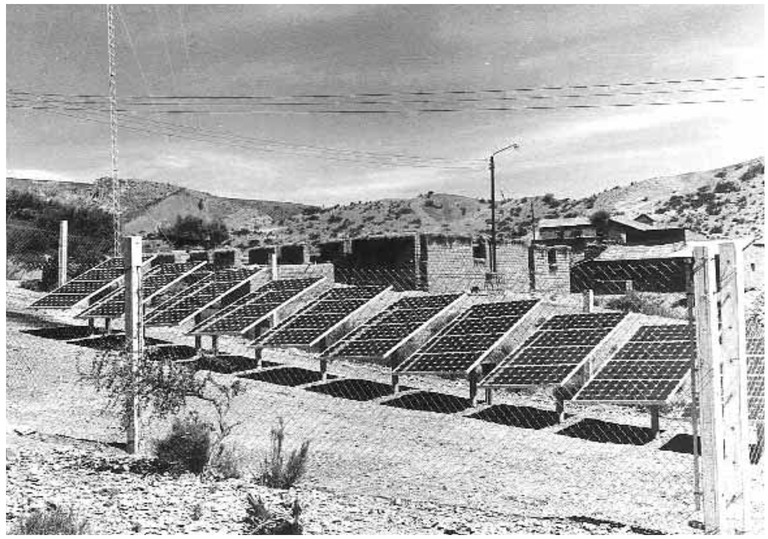
1. Introduction to Part I 3
2. Country Study: Argentina 29
3. Country Study: Bangladesh 43
4. Country Study: Brazil 65
5. Country Study: Senegal 77
6. Country Study: Zimbabwe 101
7. Part I – Synthesis 117

Part II:
The Clean Development Mechanism and
Decentralized Renewable Energy 119

8. Introduction to Part II 121
9. Country Study: Argentina 125
10. Country Study: Bangladesh 137
11. Country Study: Brazil 147
12. Country Study: Senegal 155
13. Country Study: Zimbabwe 163
14. Part II – Synthesis 169

Conclusion 171

Part I



Linking Mitigation and Adaptation Through Energy Access

1. Introduction to Part I

1.1 Policy Context

The Eighth Conference of the Parties (COP-8) to the United Nations Framework Convention on Climate Change (UNFCCC) in New Delhi in November 2002 provides a useful starting point for examining the critical role decentralized renewable energy (DRE) can play in addressing poverty alleviation and sustainable development aspirations of developing countries, and in helping to bridge North and South climate policy concerns.

Expectations for COP-8 were not high—its initial concerns were the implementation details of the mechanisms that govern the international trade of GHG emissions credits under the Kyoto Protocol of the UNFCCC: international emissions trading, Joint Implementation (JI) and the Clean Development Mechanism (CDM). The expectations for the conference on the part of its host were somewhat higher. Conference president and Indian Minister for the Environment, T. R. Baalu, sought to align the climate issue more closely with the sustainable development aspirations of the South (Ott, 2003).

This re-orientation of the negotiations towards a focus on the South's sustainable development agenda initially was resisted by the EU who, first, insisted that mitigation (GHG emissions reduction) remain the focus, and second, attempted to start discussions on the post-Kyoto commitment period (and in so doing put the extremely contentious issue of developing country emissions back on the table). The EU's position was resisted by the South who perceived this as an attempt to deflect attention away from what it sees as the primary mitigation issue—developed country compliance with their Kyoto commitments.

The final result of this debate was the "Delhi Ministerial Declaration on Climate Change and Sustainable Development." Initially dismissed as inconsequential by seasoned climate policy veterans, the Delhi Declaration in fact reflects the conflicting perspectives of the North and South that characterized the conference and climate policy in general. The Delhi Declaration acknowledges that "significant cuts in global emissions will be necessary" to meet the Convention objective of stabilizing atmospheric greenhouse gas (GHG) concentrations, but also reaffirms that "economic and social development and poverty eradication are the first and overriding priorities of developing country partners" (UNFCCC, 2002). The key resolutions of the Delhi Declaration are given in Box 1.1.

Box 1.1 Key resolutions of the Delhi Declaration

- National sustainable development strategies should integrate more fully climate change objectives in key areas such as water, energy, health, agriculture and biodiversity, and build on the outcomes of the World Summit on Sustainable Development;
- Adaptation to the adverse effects of climate change is of high priority for all countries;
- Developing countries are particularly vulnerable, especially the least developed countries and small island developing nations. Adaptation requires urgent attention… as well as capacity-building for the integration of adaptation concerns into sustainable development strategies…;
- International cooperation should be promoted in developing and disseminating innovative technologies in respect of key sectors of development, particularly energy;
- Technology transfer should be strengthened, including through concrete projects and capacity-building in all relevant sectors… Technological advances should be promoted through research and development, economic diversification and strengthening of relevant regional, national and local institutions for sustainable development;
- Access should be improved to reliable, affordable, economically viable, socially-acceptable and environmentally-sound energy services and resources, taking into account national specificities and circumstances…;
- Actions are required to diversify energy supply by developing advanced, cleaner, more efficient, affordable and cost-effective energy technologies…;

- Actions are required at all levels, with a sense of urgency, to substantially increase the global share of renewable energy sources with the objective of increasing their contribution to total energy supply… ensuring that energy policies are supportive to developing countries' efforts to eradicate poverty; and
- Annex I Parties should further implement their commitments under the Convention, including, for Annex II Parties, those relating to the provision of financial resources, technology transfer and capacity-building, and demonstrate that they are taking the lead in modifying longer-term trends in anthropogenic greenhouse gas emissions, consistent with the ultimate objective of the Convention, through the adoption of national policies and corresponding measures for the mitigation of climate change."

The Delhi Declaration can be interpreted as an indicator that the complex issues of North-South equity that lurk behind climate change can no longer be ignored (Ott, 2003) and are, for most intents and purposes, synonymous with fundamental sustainable development challenges.

The CDM is perhaps the most novel economic instrument ever conceived to bridge the sustainable development aspirations of the North and South. However, its detailed design and implementation protocols render it a work in progress. The CDM is a market-based mechanism under the Kyoto Protocol of the UNFCCC that allows companies in industrialized countries to acquire certified emissions reduction credits (CERs) from projects in developing countries that reduce GHG emissions and produce sustainable development benefits, primarily through the transfer of clean energy technology. The history of the CDM is a tumultuous one and reflects years of contention between the North and South over who bears the burden of responsibility for climate change. The CDM originally emerged from a Brazilian proposal to distribute the burden of emissions reductions among Annex-I parties to Kyoto Protocol based on each countries cumulative GHG emissions, and hence its cumulative impact on the global climate. The Brazilian proposal also called for a penalty mechanism, the "Clean Development Fund," supported by payments from Annex-I countries who exceeded their emissions targets. The fund would, in turn, finance emissions reduction projects in non-Annex-I countries.

The Brazilian proposal was not adopted, but the concept of the Clean Development Fund did inspire the CDM to emerge out of a political compromise between the U.S. and the G77+ China (Goldemberg 1998). The U.S. wanted an emissions trading regime with maximum flexibility and mandatory emissions limits for all countries—including the developing ones—which was strenuously resisted by the South. The CDM allows developing country participation in emissions trading, but without any constraints on their total emissions.

The original Brazilian proposal is also significant as it reflects the widely-held view among the G77+ China that they bore miniscule responsibility for anthropogenic climate change given their very small cumulative emissions compared to the North—even though the South's emissions are increasing rapidly. Any attempt to impose mandatory emissions limits on the South was thus perceived as a distortion of historical responsibility for climate change and, more importantly, a constraint on development. In the negotiation process leading up to the original climate change convention (the UNFCCC), India stressed that an "equitable" response to climate change would require that developed countries reduce emissions on a per capita basis to the point where they converge with rising per capita emissions in the developing world (Rajan, 1997). In this view, the burden of responsibility had to fall on developed countries who, in addition to bearing historic responsibility for climate change, had the required financial and technological resources to decarbonize their economies.

Mitigating GHG emissions is still a marginal policy concern for developing countries, yet in the face of rapid emission increases in some countries, the engagement of high emitting southern countries in an equitable and comprehensive post-Kyoto mitigation strategy is probably inevitable. The current policy stalemate (intensified by the inability of the North to ratify the prerequisite Kyoto Protocol), though, inhibits the initiation of a meaningful post-Kyoto dialogue (IEA, 2002a).

Unlike mitigation, adaptation to climate change (the planned response to the negative impacts of climate change) is a major policy priority for developing countries. The Intergovernmental Panel on Climate Change (IPCC, 2001) concluded that the least developed countries are the most vulnerable to climate change impacts that exacerbate existing environmental and resource stress and poverty. Adaptation to climate change is, therefore, increasingly aligned with the sustainable development aspirations of the South, as forcefully expressed in the Delhi Declaration.

Adaptation is now a mainstream climate policy issue. The Marrakesh Accords established at COP-7 in Marrakesh, Morocco, included an "Adaptation Fund," basically a two per cent tax on CDM transactions to finance high-priority adaptation projects in developing countries. However, the increasing realization that climate change adaptation is largely synonymous with sustainable development clarifies that the Marrakesh adaptation fund—which very optimistically might accrue US$100 million annually—will simply not suffice, given the scale of the global sustainable development (SD) challenge.

Marrakesh also established other rules surrounding the CDM: the full fungibility of the CDM with other trading mechanisms; eligibility of afforestation and reforestation projects that sequester carbon (also known as "carbon sinks"); the principle that developing countries should establish their own SD eligibility criteria for the CDM investments that they choose to host; and "fast-track" approval procedures for a specific class of small-scale renewable energy and energy efficiency projects (PIAD, 2003).[1] The basic rationale for extending this special consideration to small-scale, decentralized energy and energy efficiency projects stems from the policy consensus that projects of this scale generate proportionally higher socio-economic and ecologic benefits—particularly in chronically impoverished regions of the developing world. Fast-tracking small-scale projects "levels the playing field'" and reduces the risk that the CDM market will be dominated by large-scale centralized projects with lower transaction costs, thus undermining the CDM's purpose of promoting sustainable development in host countries while mitigating greenhouse gas emissions (Bosi, 2001).

The central theme of this book is that well-designed decentralized renewable energy projects are in fact a mitigative *and* an adaptive response to climate change. DREs address core sustainable development priorities and build adaptive capacity to climate change, without increasing GHG emissions. Building coherent climate policy around the DRE option is a win-win opportunity that overcomes the policy divide by addressing the South's adaptation needs and the North's mitigation priorities. In supporting strong DRE-based climate policy, the North can build the good faith necessary to meaningfully engage the South in a post-Kyoto phase of climate negotiations.

Despite the strong rationale for DRE-based climate policy, developing country SD criteria and CDM implementation strategies are generally not well-aligned with the DRE option. Nor has the North adequately committed to the necessary research and development or capacity-building in the South to adequately implement DRE policy. This book explains the DRE mitigation-adaptation nexus, reviews the DRE and CDM experience in five developing countries, and provides synthesis and recommendations as to how the CDM should be supported in host countries, by investor countries and in a multilateral sense by agenda-setting institutions like the World Bank and the United Nations.

1.2 Climate change mitigation: the broad view

The twentieth century is accurately described as the golden era of fossil fuels. Fossil fuels supplanted biomass as the dominant primary energy source globally in the 1890s and their use increased 16 times between 1900 and 2000. Even more impressive has been the spectacular rise in electricity generation and consumption. In 1900, electricity generation accounted for less than two per cent of fossil fuel use compared to over 30 per cent by 2000.

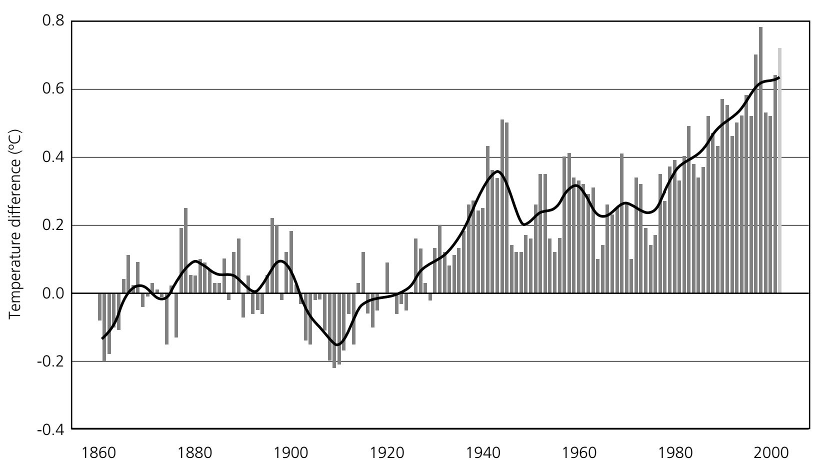
By the middle part of the twentieth century, the environmental implications of exponentially-increased fossil fuel consumption began to emerge. Arrhenius (1896) outlined the basic physics of the greenhouse effect and global warming in the late nineteenth century: geometric atmospheric carbon dioxide (CO_2) increases from fossil fuel combustion, arithmetic surface temperature increases with more warming in polar regions and less near the equator. Revelle and Seuss (1957, p.19), however, ushered in the modern era of global warming concern with their observation that "human beings are now carrying out a large-scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future. Within a few centuries, we are returning to the atmosphere and oceans the concentrated organic carbon stored in sedimentary rocks over hundreds of millions of years."

The Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC, 2001) documents our current understanding of the early outcomes from this unplanned atmospheric experiment, concluding that:

- global average surface temperatures of the Earth have risen 0.6 (+/- 0.2) degrees centigrade during the twentieth century;
- the global average surface temperature is projected to further increase by 1.4 to 5.8 degrees centigrade by 2100 relative to 1990;
- the globally-averaged sea level is projected to rise 0.09m to 0.88m by 2100;
- altered precipitation patterns will accompany climate warming and both these manifestations of climate change will vary considerably by region; and
- long-term, systematic studies indicate that climate change effects—notably shrinking glaciers, thawing permafrost, late freezing and early break-up of lake and river ice, and poleward and altitudinal shifts of plant and animal range—are already occurring.

The general link between CO_2 emissions and global warming is not incontrovertible, but the recent scientific evidence is compelling. Figure 1.1 shows the last 140 years of globally-averaged surface temperatures. The recent warming reinforces a strong warming period that began about 20,000 years ago, preceded by several cycles of even warmer periods through the last several hundred thousand years. Figure 1.2 shows a superposition of global temperature and average atmospheric concentrations of the two major GHGs: CO_2 and methane (CH_4). The evidence linking those earlier warming periods with elevated atmospheric GHG concentrations is incomplete but mounting. Currently, the carbon flow dynamics among marine, terrestrial, biotic and atmospheric reservoirs are simply not fully understood (Kump, 2000), (Smil, 2002). The science, however, that anthropogenic CO_2 emissions are the primary global warming driver in the last century and a half, is substantially more complete. Hansen *et al.* (2000) determined that CO_2 and CH_4 are the primary anthropogenic "forcing agents" of global warming since 1850.

Figure 1.1 1860–2001 Temperature anomalies

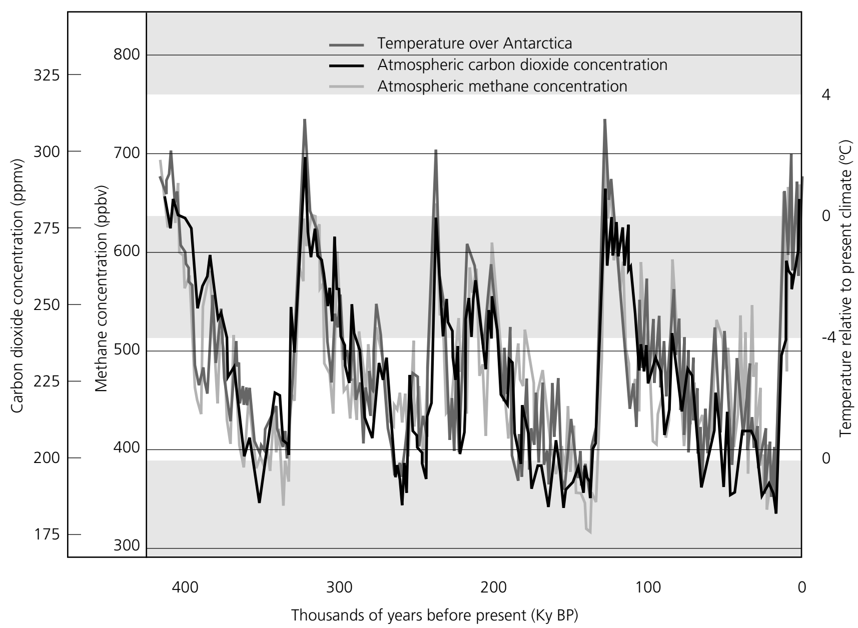


Source: Hadley, 2002

The risk that the Kyoto Protocol attempts to begin to manage is that continued atmospheric forcing from anthropogenic GHG emissions will intensify a normal warming period, causing a runaway greenhouse effect with potentially catastrophic impacts for the biosphere and human civilization. In essence, the Kyoto Protocol, which attempts to mitigate CO_2, CH_4 and nitrous oxide (N_2O) emissions,[2] applies the precautionary principle based on the consensus scientific opinion expressed by the IPCC. In the absence of definitive science, the weight of evidence suggests anthropogenic causation of climate change and, without emissions mitigation, we bear a risk of irreversible climate change. Seemingly straightforward, an integrated GHG mitigation perspective must contend, however, with two related features of CO_2 emissions and fossil energy use: deforestation and energy deprivation.

Until about 1910, the average carbon flux to the atmosphere from land-use change exceeded that from fossil fuels, not coincidentally shortly after the time that fossil fuels surpassed biomass energy as the dominant primary energy source (Smil, 2002). The land-based carbon flux includes all anthropogenic land-use changes: agriculture land clearing; biomass consumption as energy; and timber extraction. Tropical deforestation accounts for about 63 per cent of the cumulative land-based carbon flux between 1850 and 2000, the largest portion of which came from Asia. This trend continued and intensified during 1990s (Houghton, 1999), (Houghton and Hackler, 2001). Land-use change still accounts for about a quarter of total carbon emissions and is equal to about a third of all fossil fuel emissions.

Figure 1.2 Variations of temperature, methane and atmospheric carbon dioxide concentrations derived from air trapped within ice cores from Antarctica



Source: IPCC, 2001b

Furthermore, energy consumption (including fossil fuels) is distributed essentially bimodally throughout the world. Energy consumption averages about 60 gigajoules (GJ)/capita, but very few countries are anywhere close to the global average. A cluster of high-income countries[3] consumes about 150 GJ/capita, whereas another cluster of low-income countries[4] consumes about 25 GJ/capita. The extremes of energy deprivation and profligacy are even starker: sub-Saharan African countries consume about 0.6 GJ/capita, whereas North Americans consume about 300 GJ/capita.

Essentially, neither fossil fuels nor electrification ever penetrated a broad swath of humanity. About two billion people have no access to modern energy services of any kind and rely on traditional biomass for primary energy. Biomass (fuelwood, agricultural residue and animal dung) still comprises well over 90 per cent of the primary energy supply in the rural areas of many developing countries. The regions of the world where biomass energy dependency is highest—Latin America, Sub-Saharan Africa and South Asia—are the same regions where the terrestrial carbon fluxes from deforestation are highest.

The high carbon flux from terrestrial sources and subsistence biomass energy dependency are different, but closely-related, characteristics of chronic rural under-development. Biomass extraction for energy is not the sole, or even the principal, driver of deforestation. Poverty, marginalized agricultural and ecological conditions (often exacerbated by climate change) and a lack of alternative livelihood opportunities are the general drivers of deforestation. Forest destruction takes many forms, including expansion of agricultural lands, charcoal production, fuelwood extraction and timber production (Geist and Lambin, 2001). Charcoal production and unmanaged fuelwood extraction are direct links between energy deprivation and deforestation, whereas agricultural expansion is an indirect link. Rural agroecosystems in the developing world are in fact a nexus of major environmental issues beyond climate change. Biodiversity conservation, for example, will not succeed if deforestation is not checked, which requires agricultural productivity intensification, which in turn requires rural development and infrastructure investments—a critical element of which is modern energy services (Mellor, 2002), (WEC/FAO, 1999).

The key observation thus far is that any comprehensive greenhouse gas mitigation strategy is inextricably linked to land use and sustainable development in the majority of the world. For reasons of both equity and function, coherent climate policy requires expanded energy services in the developing world *particularly* in rural areas where energy deprivation is acute, the environmental outcomes of energy deprivation severe, and where non–GHG renewable energy sources are technically viable. The logic underlying the Kyoto Protocol's CDM, and the fast-track modalities for small-scale renewable energy and energy efficiency projects within it, are, therefore, quite sound. Even if Kyoto is fully ratified and its targets achieved, emissions from the North would decrease by a few per cent and the South's emissions would still rise. The profound challenges, therefore, are developing the capacity and preparedness to tackle rural energy deprivation given the enormous scale of the issue. Maximizing the sustainable rural development and technology transfer content of the current CDM as a prerequisite to a similar post-Kyoto instrument is evidently a large part of this challenge.

1.3 Renewable Energy and Visions of Sustainability

"Sustainable development" has become synonymous with a transition to a desirable, sustainable and equitable global future. Scenario construction is the conceptual and analytical tool frequently used to build a shared understanding of sustainable future worlds. Scenarios are neither predictions nor forecasts; they are merely internally consistent cognitive models of how the world could look in the future. Military planners were the first to use scenario development with the practice spreading into corporate boardrooms by the 1970s, most famously through the Shell Group's planning of corporate-wide response strategies in the wake of the first "oil crisis" (Schwartz, 1991).

Because global sustainability (particularly climate stability) depends heavily on the characteristics of global energy use, a large body of literature linking energy scenarios and sustainable development pathways has emerged in recent years. Energy scenarios that describe sustainability are not value-free. Although some purely descriptive scenarios explore the future without preconceived endpoints, sustainability scenarios are explicitly normative, exploring development paths that lead to a desirable future (such as the stabilization of atmospheric CO_2 concentrations).

The International Institute for Applied Systems Analysis (IIASA) and the World Energy Council (WEC) jointly undertook a five-year study entitled Global Energy Perspectives (Nakicenovic *et al.*, 1998). The key objectives of the IIASA-WEC study were to integrate near-term strategies (up to 2020) with long-term possibilities (up to 2100), and to ensure consistency, reproducibility and transparency with a unified methodological framework linking databases, models and assumptions. Three basic scenarios span a wide range of possible global futures in the IIASA-WEC study:

- Scenario A: "High-growth" with vigorous economic development and rapid technological advance. One of the variants in this scenario ("A3") includes many features consistent with sustainable development.
- Scenario B: "The middle course" with intermediate economic growth and modest technological improvements.

- Scenario C: "Ecologically-driven" incorporating aggressive environmental and energy taxes for simultaneous environmental protection and North-South wealth transfer. Scenario C includes two variants ("C1 and "C2") that assume new renewable energy technology with and without nuclear energy respectively. Both case C scenarios assume heavy decentralization of energy systems, reliance on local solutions and relatively greater investment in end-use sectors rather than new generation.

Table 1.1 provides a qualitative summary of the high sustainability scenarios for several key indicators.

Table 1.1 Sustainability indicators for three energy scenarios in 2050 and 2100 compared with 1990

Indicator of sustainability	1990	Scenario A3	Scenario B	Scenario C1
Eradicating poverty	Low	Very high	Medium	Very high
Reducing relative income gaps	Low	High	Medium	Very high
Providing universal access to energy	Low	Very high	High	Very high
Increasing affordability of energy	Low	High	Medium	Very high
Reducing adverse health impacts	Medium	Very high	High	Very high
Reducing air pollution	Medium	Very high	High	Very high
Limiting long-lived radionuclides	Medium	Very low	Very low	High
Limiting toxic materials	Medium	High	Low	High
Limiting GHG emissions	Low	High	Low	Very High
Raising indigenous energy use	Medium	High	Low	Very High
Improving supply efficiency	Medium	Very high	High	Very High
Increasing end-use efficiency	Low	High	Medium	Very High
Accelerating technology diffusion	Low	Very high	Medium	Medium

Source: WEA, 2000, p. 339

We focus on Case C, as the scenario's authors describe it as most compatible with principles of sustainable development and it assumes high growth in the South and high equity (WEA, 2000, p.20). The energy sector transitions necessary to achieve sustainability are depicted in Figures 1.3 and 1.4, which respectively show primary energy consumption from 1990 to 2100 for the entire globe and for the developing world (Latin America, Africa and Asia).

Figure 1.3 Global primary energy consumption (EJ), IIASA-WEC scenario C1

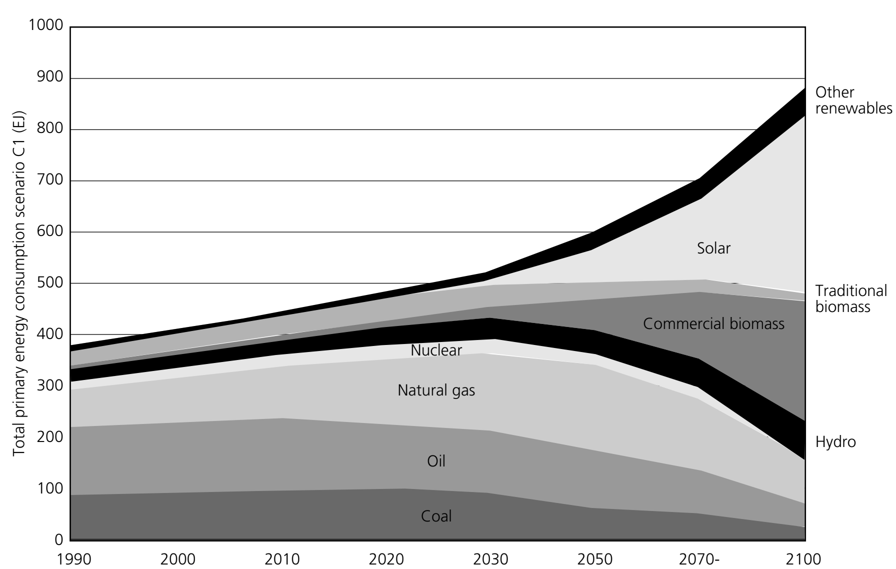
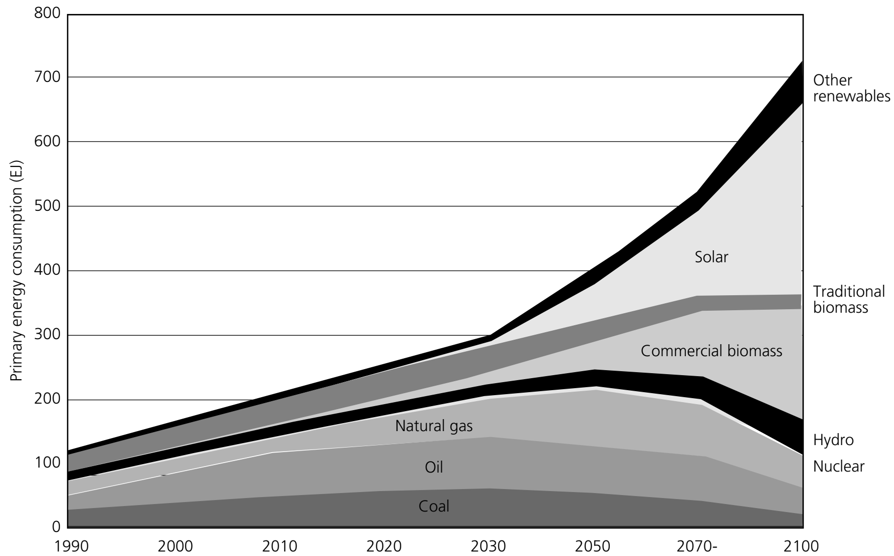


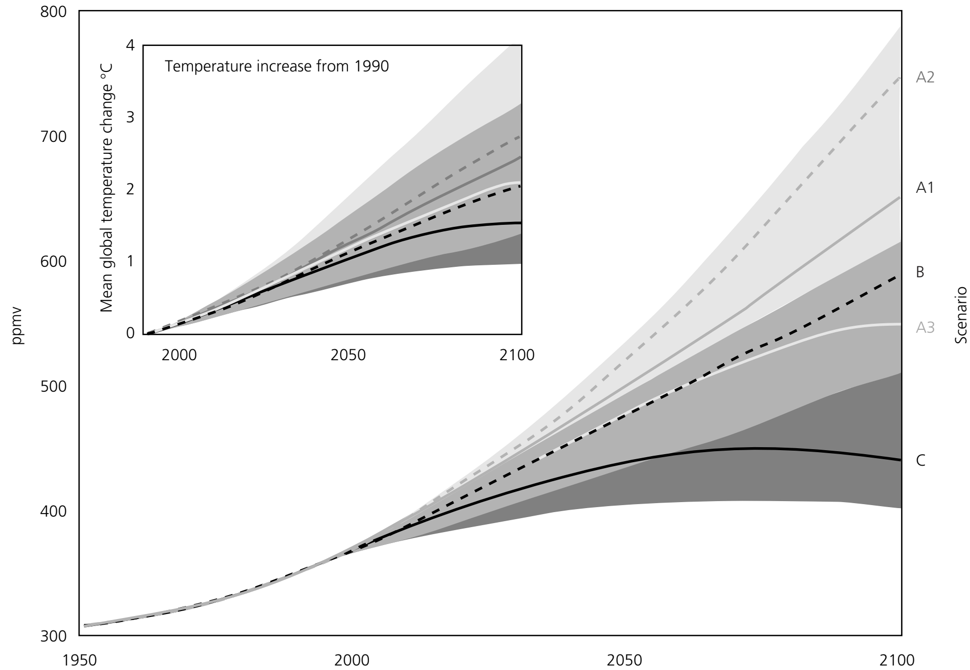
Figure 1.4 Developing world primary energy consumption (EJ), IIASA-WEC scenario C1



A prominent feature of scenario C1 is the massive transition to decentralized renewable energy in various forms (notably solar and biomass) which, according to the IIASA-WEC analysis, does stabilize atmospheric CO_2 concentrations at about 450 ppmv (Figure 1.5). The key additional insight from scenario C1 is that the most effective approach to de-carbonizing global energy systems is also consistent with resolving rural energy deprivation. Furthermore, rehabilitating degraded land for biomass energy production can also reverse GHG emissions from unmanaged land conversion—a key GHG emissions source. Given that rural energy deprivation is increasingly understood as a root cause of stunted human health, ecosystem degradation and rural under-development, DREs should be at the top of the global sustainable development agenda regardless of their significance to de-carbonizing global energy systems. In this light, decentralized renewable energy is in fact a "no-regrets" development option; immediately necessary, but also integral to long-term sustainability.

The importance of early and sustained adoption of DREs should not be understated. The global circulation models (GCMs) used to translate GHG emission scenarios into future CO_2 concentrations and temperature increases (Figure 1.5) did not consider the land and ocean carbon cycle dynamics. The most advanced GCMs now consider the joint effects of warming oceans (which absorb less CO_2) and degrading forests (which sequester less CO_2); these recent GCM simulation experiments conclude that permissible cumulative GHG emissions are much lower than had been previously estimated (Hadley, 2002). For example, the standard GCM maintained by the Hadley Centre for Climate Prediction and Research indicates that approximately 800 Gt of GHG emissions between 2000 and 2300 are permissible for a stabilized CO_2 concentration of 450 ppmv. If carbon cycle dynamics are included, much less atmospheric CO_2 is either absorbed by oceans or sequestered by forests and the permissible GHG emissions between 2000 and 2300 drops to 500 Gt. In contrast, C1, the most aggressive GHG mitigation scenario considered in the IIASA-WEC study, assumes that cumulative GHG emissions will exceed 540 Gt *by 2100*, further emphasizing the importance of wide-scale DRE adoption more rapidly than even assumed in scenario C1.

Figure 1.5 Projected atmospheric CO_2 concentrations and temperature increases for IIASA-WEC scenarios



Source: Nakicenovic et al., 1998

1.4 Adaptation, Adaptive Capacity and Sustainable Development

The IPCC's Third Assessment Report concluded that, regardless of our success at mitigating GHG emissions, we are committed to some degree of climate change. The long-residence time of atmospheric GHGs commits us to global warming well after emissions have ceased. The Kyoto Protocol moves us only incrementally towards the magnitude of emissions mitigation that may be necessary to protect the climate from dangerous anthropogenic interference. Even the most optimistic energy scenarios (see the inset plot in Figure 1.5) still project a residual 1.5 degree warming (which in light of recent coupled climate-carbon cycle modelling may be an under-estimate). The consensus scientific opinion as expressed by Working Group II of the IPCC concluded that global warming by even 1.5 degrees significantly increases climate impact risks, particularly the risks to unique and threatened systems, and the risks from extreme climate events.

The detailed specification of impacts, and hence the specification of necessary adaptation measures for particular communities and ecosystems, remains intractable to current science. The GCMs used to model climate capture global warming in broad terms, but do not have any fine-grained predictive power; furthermore, specific impacts will be an artifact of assumptions used to generate the emissions scenario driving the model. The associated adaptation prescriptions will similarly be an artifact of the scenario assumptions. The impacts approach to climate adaptation, with its inherent limitations and uncertainties has in recent years yielded to the *vulnerabilities* approach. The vulnerabilities approach, in contrast, emphasizes the role of *adaptive capacity*, an endogenous property of the system (community, region or sector) that describes the system's ability to prepare for, avoid, moderate and recover from climate exposure and climate risk *in general* (Smit and Pilifosova, 2003). The vulnerability approach "recognizes that adaptation is less about identifying and implementing specific climate change adaptation measures and more about strengthening an ongoing process wherein resources are available to identify vulnerabilities and employ adaptive management strategies, appropriate for that context, to deal with climate risks along with other risks" (Smit and Pilifosova 2003, p. 14).

System vulnerability, V, is conceptualized as a function of a system's exposure to climate change effects, E, and its adaptive capacity, A, to deal with those effects. The more exposed a system is to a particular climate stimulus, the greater the system vulnerability; conversely, the greater the adaptive capacity of the system to a given climate event, the lower its vulnerability. Smit and Pilifosova (2003, p.13) express this relationship formally as:

$$V_{it}^{\,s} = f\,(E_{it}^{\,s}, A_{it}^{\,s}) \qquad (1)$$

Where

$V_{it}^{\,s}$ = vulnerability of system i to climate stimulus s in time t

$E_{it}^{\,s}$ = the magnitude of climate change exposure of i to s in t

$A_{it}^{\,s}$ = adaptive capacity of i to deal with s in t

The implied formalism of the vulnerabilities approach belies the subjectivity regarding what adaptive capacity actually means. The IPCC stopped short of a formal definition, but did conclude that communities and nation-states are highly heterogeneous in their capacity to adapt to and mitigate climate change impacts. Perhaps unsurprisingly, the least developed countries are the least endowed with adaptive capacity and hence most vulnerable to climate change. The more extreme the climate change scenario, the greater the disparity between developed and developing countries, which reflects the progressively declining ability of least developed countries to adapt. Evidence to date of the economic damages attributable to extreme climate events indicates that least developed countries have borne much higher relative GDP costs than developed countries (IPCC, 2001a, p.7).

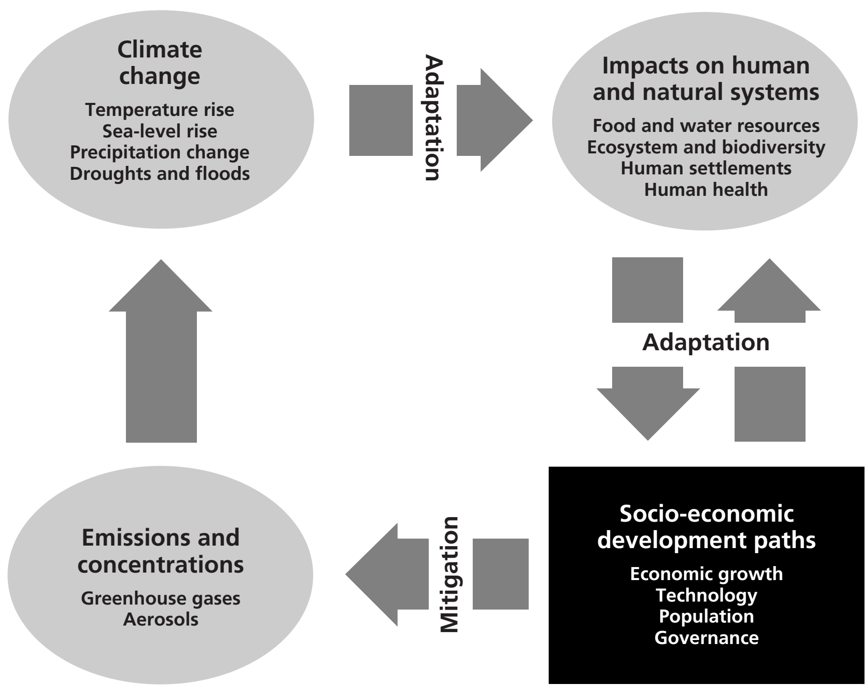
The high vulnerability of least developed countries relates more to their low adaptive capacity (known with relative certainty) than to the magnitude of any specific climate impacts (known with very low certainty). The IPCC observed that climate stresses in the most vulnerable communities exacerbate population, resource depletion and poverty pressures. Although the IPCC's review of the relevant literature did not produce a clear definition of adaptive capacity, they did observe that, "the ability to adapt clearly depends on the state of development… underdevelopment fundamentally constrains adaptive capacity, especially because of a lack of resources to hedge against extreme but expected events" (IPCC, 2001c, p.899) (Ribot *et al.*, 1996). Enhancing adaptive capacity, "involves similar requirements as promotion of sustainable development" such as resource access, poverty reduction, increased equity and increased capability to participate in local politics and actions (IPCC, 2001c, p. 899).

Low adaptive capacity is not synonymous with economic poverty; the broader sense of poverty, however that encompasses both income and non-income dimensions of deprivation (World Bank, 2002]—such as lack of access to basic social and ecosystem services, and lack of empowerment to participate in the political processes that influence one's life—are very closely related to low adaptive capacity. Indeed, extreme vulnerability to external shocks (including climate stress) is now widely understood to be a major defining characteristic of poverty (UNDP, 1997). The IPCC appropriately concluded that climate adaptation, sustainable development and improved equity can all be mutually-reinforcing if policies are advanced which lessen resource pressure, improve environmental risk management, and increase welfare for the poorest members of society (IPCC, 2001a, p. 7).

The potential synergies between sustainable development and climate adaptation were not fully developed in the IPCC's Third Assessment Report, reflecting the generally weak integration of these discourses. The linkage between sustainable development and climate change is proposed as a cross-cutting theme in the IPCC's Fourth Assessment Report (AR4), an integration that some observers regard as long overdue. Cohen *et al.* (1998) argued that the historic fissure between the sustainable development and climate change discourses is driven by differences in conceptual frameworks, definitions and language—essentially because climate change has been approached as a techno-scientific and sectoral issue and not as the inevitable manifestation of unsustainable development.

Swart *et al.* (2003) argue that identifying the key linkages between sustainable development and climate change will help repair this discursive rift. Addressing these linkages coherently can drive new socio-economic development pathways that are, for example, simultaneously adaptive to and mitigative of climate change. Despite pervasive scientific uncertainty regarding the magnitude and distribution of climate impacts, and hence the impossibility of precisely specifying adaptation strategies, we are not prevented from pursuing socio-economic development paths that mitigate emissions, minimize impacts and build adaptive capacity—all of which are inextricably tied to sustainable development. In the context of the integrated assessment framework adopted in the IPCC Synthesis Report (IPCC, 2001d), the sustainable development challenge is essentially to describe the content of socio-economic development paths (the box in the lower right quadrant of Figure 1.6) that are simultaneously mitigative and adaptive capacity-building.

Figure 1.6 Simplified representation of an integrated assessment framework for anthropogenic climate change



Source: IPCC, 2001d

In a background report for the TAR, the IPCC produced a *Special Report on Emissions Scenarios* (SRES) (Nakicenovic and Swart, 2000). The objectives of the SRES were similar to, and in part based on, the earlier IIASA-WEC study: to explore development pathways associated with different future emissions scenarios. Swart *et al*. argue that the SRES authors implicitly described simultaneously adaptive and mitigative development paths. Although the SRES authors did not include vulnerability statements in their scenario narratives, Swart *et al*. argue that these can be inferred. The assumptions underlying SRES Scenario A2 (slow and inequitable global economic development, high population growth, less rapid technological change) imply that adaptive capacity will stagnate, exacerbating climate vulnerability. In contrast, the most mitigative emissions scenarios (particularly B1 which broadly corresponds to the "ecologically-driven" C scenarios) address local and regional sustainability issues, emphasize appropriate technology, human and social capital development, and North-South equity (Nakicenovic *et al*., 1998), (Nakicenovic and Swart, 2000). One can therefore infer, argue Swart *et al*., that B1 also has high adaptive capacity and the lowest vulnerability.

The details, however, of the development pathway consistent with climate goals and synonymously sustainable development remain unspecified largely because sustainable development remains ill-defined and culturally contingent (Robinson, 2002). Swart *et al*., however, list some of the key and unambiguous sustainable development-climate change linkages: desertification, land degradation and food production; land use, land-cover change and biodiversity; forestry; and quantity and quality of water resources—all of which relate to the maintenance of critical ecosystem services.

We argue here that the critical linkages between sustainable development and climate change are further clarified (particularly the large synergies between adaptation and mitigation) if one interprets sustainable development using the poverty alleviation priorities counselled by the World Summit on Sustainable Development Plan of Implementation (WSSD, 2002). Poverty is both a driver and an outcome of these ecosystem-climate linkages. The poverty alleviation lens on sustainable development, can move us beyond the rather platitudinous observation that the poor are endowed with the least adaptive capacity and hence are most vulnerable to climate change, to practical intervention policy. Furthermore, a critical, integrative poverty alleviation measure, appearing on both the mitigation and adaptation ledgers, and essential for achieving the desired sustainable development pathways, is decentralized energy provision. The logic for asserting decentralized energy provision as an adaptation strategy is incomplete, however, without first establishing that poverty and energy deprivation are highly correlated.

1.5 Energy and Poverty

Following a conspicuous near-absence at the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, energy has made a steady ascent to the forefront of the global sustainable development agenda. Energy is not mentioned in the Rio Declaration on Environment and Development, did not merit a chapter in Agenda 21 (there are 40 chapters), and is the subject of no convention (although it is a key implicit concern of the UNFCCC). Energy is completely absent from the Agenda 21 chapter devoted to combating poverty, and merits only passing consideration in later chapters concerned with changing consumption patterns, promoting sustainable human settlement development, protection of the atmosphere, deforestation and the management of fragile ecosystems, and sustainable agriculture and rural development.

As Agenda 21 and the Rio Conventions were being implemented throughout the 1990s, energy issues—primarily the catalytic role energy plays in alleviating poverty—came increasingly to the fore. The United Nations Commission on Sustainable Development (CSD), the UN body charged with monitoring and reporting on the implementation of the Rio agreements, paid increasing attention to energy issues. At its ninth session in 2001, the CSD recognized that poverty reduction goals, expressed by the Millennium Assembly of the United Nations in 2002, would not be met without increased access to modern energy by the world's poor (GFSE, 2002).

The resulting prominence of energy issues at the 2002 WSSD is striking. The strong emphasis on energy provision as essential to poverty reduction suggests a significant shift in mainstream development policy thinking compared to the Rio era. The third point in the poverty eradication chapter of the WSSD's Plan of Implementation urges "actions and efforts… at all levels to improve access to reliable and affordable energy services for sustainable development sufficient to facilitate the achievement of the Millennium Development Goals, including the goal of halving the proportion of people in poverty by 2015, and as a means to generate other important services that mitigate poverty, bearing in mind that access to energy facilitates the eradication of poverty" (see Box 1.2).

The WSSD's recognition of energy deprivation as a critical determinant of poverty subsequently influenced the Delhi Declaration, which urged parties to the climate convention to recognize that expanded energy accessibility in the South had to be part of a comprehensive sustainable development orientation to climate change. The prominence of energy access as critical to poverty alleviation can be traced to a spate of reports which emerged in the late 1990s.

A World Bank (1996) *Development in Practice* series publication, "Rural Energy and Development: Improving Energy Supplies for Two Billion People," called attention to the continued economic and ecologic and physical impoverishment of rural people, the failure of conventional models of energy services provision, and the need for new rural energy development models. A co-publication by the World Energy

Council and the Food and Agriculture Organization of the UN, "The Challenge of Rural Energy Poverty in Developing Countries" (WEC/FAO, 1999), further highlighted the magnitude of the challenges as well as the potential for innovative financial instruments and technologies to promote rural energy services. The WEC/FAO study called attention to bioenergy, concluding that traditional biomass dependency will persist for many decades. Recent successes in community-based forestry management, however, indicate that continued bioenergy use can be a source of hope rather than despondency. Biomass is an indigenous, potentially sustainable renewable resource, but it must be managed and harvested effectively with strong local participation and used efficiently, which is rarely the case. Bioenergy can promote biodiversity; it provides lower risk GHG mitigation than forest sequestration; it provides a basic livelihood need for rural people and it can be transformed into electricity. One of the key messages of the WEC/FAO study was that, since the prospects for significantly reduced bioenergy dependency in the near to medium term are slim at best, we should make the best possible use of this resource, which includes transforming it into liquid and gaseous fuels and electricity.

The *World Energy Assessment: energy and the challenge of sustainability,* a co-publication of the United Nations Development Programme, the United Nations Department of Economic and Social Affairs and the World Energy Council (WEA, 2000), provided a comprehensive overview of the role that energy plays in achieving the inter-related economic, social, and environmental objectives of sustainable human development. The *World Energy Assessment* expended considerable effort documenting developing country and rural energy issues, including:

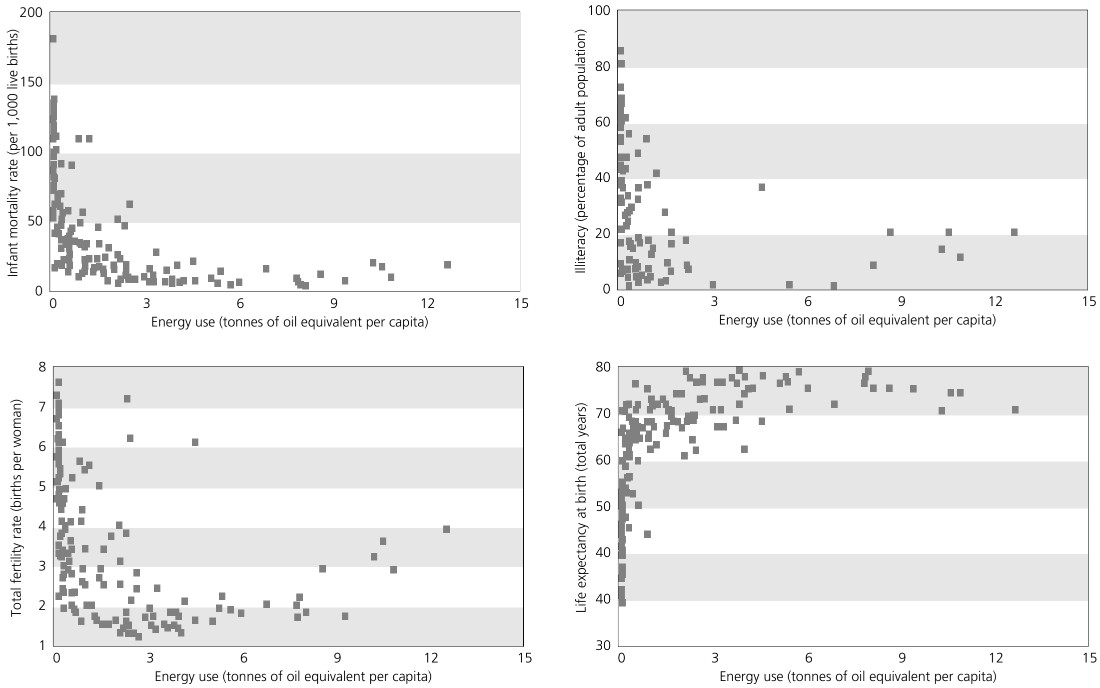
- The evidence that energy services are highly correlated with several key indicators of human development; infant mortality, illiteracy, life expectancy and fertility as well as the composite Human Development Index (Figure 1.7a and 1.7b).
- The concept of the *energy ladder*, the general progression of humanity from fuelwood consumption to the use of energy carriers that are more convenient and efficient. Higher rungs on the energy ladder include charcoal, kerosene, liquefied petroleum gas and electricity. Humanity's ascent of the energy ladder is not guaranteed and if alternatives are neither available nor affordable, households and communities can also descend the energy ladder to lower quality forms of biomass, including animal dung and crop residue.
- The institutional and technological potential for expanding rural energy supply, including the large potential for DRE including bioenergy systems. The World Energy Assessment also highlighted that energy services must be integrated with decentralized rural development, observing that, "in the many places where integrated rural development has been pursued, the availability of affordable modern energy services has proven to be a catalyst for economic and social transformation" (WEA, 2000, p.381).

The International Energy Agency released a chapter of their influential World Energy Outlook (WEO) at the WSSD entitled "Energy and Poverty." This IEA contribution was essentially a synthesis of the aforementioned reports, and reiterated many of the key energy-poverty linkages; among their key assertions were that:

- Access to electricity and other modern energy sources is a necessary, but not sufficient, requirement for economic and social development…modern energy services enhance the life of the poor in countless ways (IEA, 2002b, p. 6); and
- The extensive use of biomass in traditional and inefficient ways and the limited availability of modern fuels are manifestations of poverty (IEA, 2002b, p. 6).

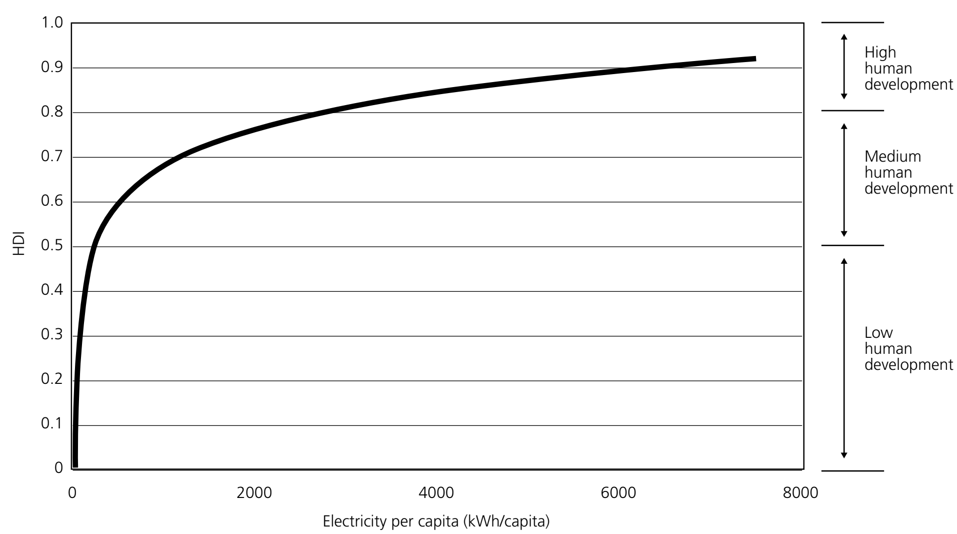
This emergent policy consensus that energy services are integrally related to poverty alleviation was instrumental in the prominence of energy issues in the WSSD Plan of Implementation (see Box 1.2)

Figure 1.7a Commercial energy use and selected social indicators



Source: WEA, 2000; based on data reported in World Bank, 1998

Figure 1.7b Electricity consumption and the Human Development Index (HDI)



Source: UNDP, 1998. The HDI consists of three equally weighted components: GDP per capita, life expectancy and education.

Box 1.2 WSSD Plan of Implementation: energy and poverty eradication actions

a. improve access to reliable, affordable, economically viable, socially acceptable and environmentally-sound energy services and resources, taking into account national specificities and circumstances, through various means, such as enhanced rural electrification and decentralized energy systems, increased use of renewables, cleaner liquid and gaseous fuels and enhanced energy efficiency, by intensifying regional and international cooperation in support of national efforts, including through capacity-building, financial and technological assistance and innovative financing mechanisms, including at the micro-, and meso-levels, recognizing the specific factors for providing access to the poor.

b. improve access to modern biomass technologies and fuelwood sources and supplies and commercialize biomass operations, including the use of agricultural residues, in rural areas and where such practices are sustainable.

c. promote a sustainable use of biomass and, as appropriate, other renewable energies through improvement of current patterns of use, such as management of resources, more efficient use of fuelwood and new or improved products and technologies.

1.6 Energy, Ecosystems, and the Millennium Development Goals

While the positive economic outcomes of increased energy use are intuitive, the positive social and ecological outcomes of rural energy provision are less obvious. They are, however, central to the key claims of this publication: decentralized renewable energy can be a climate change mitigation strategy as well as an adaptation strategy—and is integral to sustainable development. The dual role of DRE with respect to climate policy objectives can be explained with a more careful examination of the energy dimensions of poverty and vulnerability. First, poverty is now more clearly understood as encompassing both income and non-income dimensions of deprivation (World Bank, 2002). The constituents of poverty include lack of income, material means and livelihood opportunities; poor or no access education, health and safe water; and a lack of empowerment to participate in the political processes and decisions that affect one's life. Extreme vulnerability to external stresses and shocks (including but not limited to climate change) is also one of the major features of poverty (UNDP, 1997), (World Bank, 2002).

The re-orientation of SD goals to poverty alleviation at the WSSD does not diminish the importance of environmental goals. The WSSD plan, rather, clarifies that environmental degradation is both a driver and an outcome of poverty and that comprehensive policies to alleviate poverty necessarily entail improved environmental management. The critical dimensions of human poverty further illuminate these linkages:

- *Livelihoods:* the poor tend to be most reliant on non-market ecosystem services and the direct use of natural, most severely affected by ecosystem degradation or limited access to ecosystem services.[5]
- *Health:* the poor suffer most when water, land, and air are polluted, and environmental risk factors are a major source of health problems in developing countries.
- *Vulnerability:* the poor are most exposed to environmental risks and environment-related conflicts, and have the least coping ability (or indeed adaptive capacity) when they occur.

Energy's central role in poverty alleviation and vulnerability reduction emerges by first recognizing the overlap between the abjectly poor and the energy deprived. About two billion people world-wide subsist on less than $1 a day; the same number lack access to commercial energy. Furthermore, the World Energy Assessment Report (WEA, 2000) reports that two billion people have no access to clean and safe cooking fuels, relying mostly on traditional biomass. 1.7 billion people have no access to electricity—most of whom also fall into the categories of abjectly poor and biomass energy dependent. Rural people meet their basic energy needs utilizing unsustainable wood supplies, crop residues and manure at a very high human energy cost—a relentless daily burden borne mainly by women and children. Moreover energy consumption patterns tend to aggravate poverty, by further degrading ecosystems and agricultural productivity (WEC/FAO, 1999), (WEA, 2000).

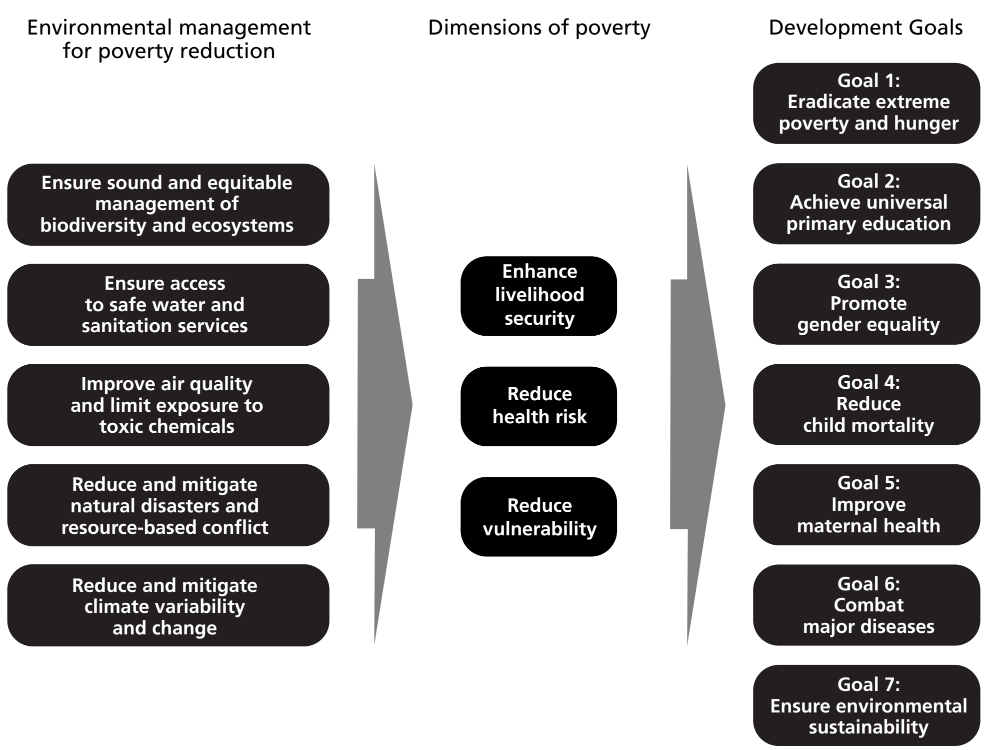
The plight of the rural poor is further exacerbated by their powerlessness in the face of the institutions and policies that influence their livelihoods. Yet any credible poverty alleviation strategy should recognize that the poor do possess social capital and are traditional stewards of their environment. In general, the poor are acutely aware of their dependence on ecosystem services and are capable of identifying priority management actions to protect them (Duraiappah, 2002).

The role that energy plays in poverty alleviation, ecosystem management and vulnerability reduction is further examined:

- first, by reviewing a general framework for linking environmental management, poverty and the Millennium Development Goals;
- second, the relationship between decentralized energy services provision and environmental management; and
- third, the direct relationship between vulnerability reduction and the Millennium Development Goals.

Figure 1.8 shows a conceptual schematic of the relationship between environmental management, the dimensions of poverty, and the Millennium Development Goals. The diagram intends to convey the main pathways between environmental conditions and dimensions of poverty, although the authors acknowledge that in reality the linkages are dynamic and inter-connected (World Bank, 2002).

Figure 1.8



Source: World Bank, 2002

Figure 1.9

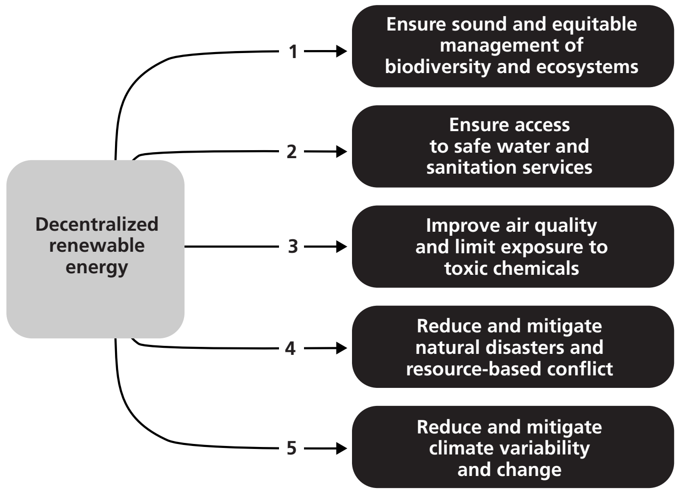


Figure 1.9 illustrates the relationship between decentralized renewable energy services provision and the environmental management drivers associated with poverty alleviation. Renewable energy does not ensure a positive environmental management outcome, but with sound physical and institutional design, renewable energy contributes to positive outcomes in all cases. The linkages in Figure 1.9 are described as follows:

1. DREs contribute to the sound and equitable management of biodiversity and ecosystems by lessening pressure on natural forests in several important ways:
    - DREs improve agricultural productivity by providing energy for irrigation pumping and post-harvest processing. These productivity improvements can in turn reduce pressure to convert forest to agricultural land otherwise required to maintain of increase productivity (Ravindranath and Hall, 1995), (FAO,2002).
    - If bioenergy feedstock is produced by afforestation on degraded land, the deforestation pressure on native forests is reduced and biodiversity conserved (Sudha and Ravindranath, 1999).
2. DREs can contribute to ensuring access to safe water and sanitation services. Access to deep groundwater (generally much safer and cleaner than surface water sources) is often constrained by a lack of energy for pumping (Ravindranath and Hall, 1995), (WEC/FAO, 1999).
3. DREs such as renewably-generated electricity for household lighting or bioenergy-derived liquid fuels for cooking, or the introduction of improved cookstoves to make more efficient use of traditional biomass all limit the exposure to the toxic by-products of traditional biomass combustion. In the rural third world, traditional biomass provides almost all primary energy demands, the largest use of which is for cooking. Despite the widespread perception that the worst air pollution occurs outdoors in urban areas, the most severe chronic exposure to airborne pollutants occurs among rural women and children from indoor sources due to biomass combustion in primitive, inefficient stoves. The use of residual biomass fuels such as crop litter and dung exacerbate the problem as they generally produce more smoke and require longer cooking times (Smith, 1993), (WEC/FAO, 1999), (WEA, 2000).
4. DRE based on bioenergy can reduce and mitigate natural disasters such as droughts and floods. If bioenergy feedstock is also produced by afforestation in degraded watersheds, floods and droughts can be attenuated by improved watershed function through reduced run-off and increased deep percolation (Pal and Sharma, 2001), (Perry *et al.*, 2001).

5. DREs reduce and mitigate climate variability and change. DREs do not emit greenhouse gases, or in the case of sustainably harvested bioenergy is "carbon-neutral"; the next generation of biomass sequesters CO_2 equivalent to that released on combustion—but still permanently displaces competing fossil fuels (Schlamadinger *et al*., 2001).

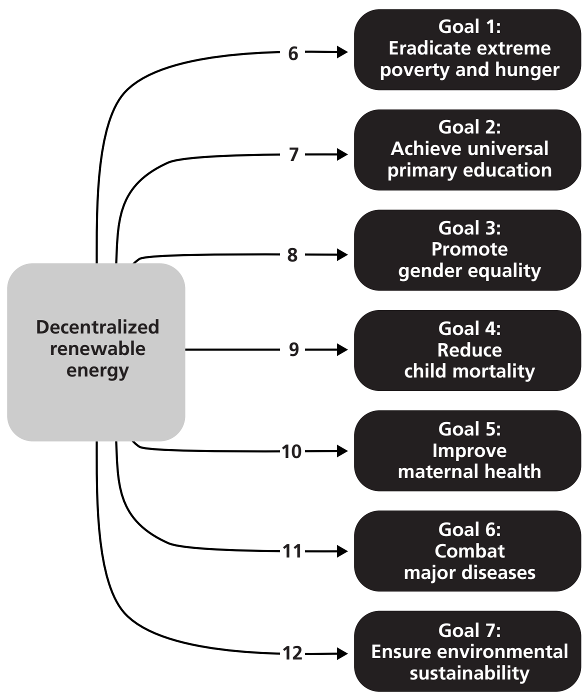
In addition to the linkages between DREs and the proximate environmental drivers of poverty alleviation shown in Figure 1.9 and described above, Figure 1.10 illustrates the direct linkages between DREs and the Millennium Development Goals. High quality energy services in general, and not specifically DREs, are positively associated with development goals. However, as will be explained in relation to Goal 7, DREs may be the only practical option for providing the required energy services. The individual linkages are elaborated as follows:

6. Goal 1: Eradicating extreme poverty and hunger. At the most basic level, eradicating extreme poverty and hunger revolves around food and water security; energy for cooking, irrigation and agricultural post-processing is essential (Ravindranath and Hall, 1995), (WEC/FAO, 1999).
7. Goal 2: Achieve universal primary education. Better energy access promotes universal education in two fundamental ways. Improved accessibility of bioenergy reduces a major labour burden on women and children—particularly girl children—and improves their opportunities for education (Agarwal, 1997), (WEC/FAO, 1999), (Malhotra, Neudoerffer and Dutta, 2004). Furthermore, household electrification improves the quantity and quality of lighting, the provision of which is very important for encouraging home study and education (Chakrabarti and Chakrabarti, 2002), (IEA, 2002).
8. Goal 3: Promote gender equality. Energy accessibility and quality directly affect women. Women comprise 70 per cent of world's poor. Women and children are the primary gatherers and user of traditional bioenergy (fuelwood, crop residue, animal dung). Women are most severely affected by environmental degradation and bioenergy shortages, and are the primary beneficiaries of increased bioenergy accessibility and improved quality and quantity of household energy services (Cecelski, 1987), (IEA, 2002), (Malhotra, Neudoerffer and Dutta, 2004).
9. Goal 4: Reduced child mortality. Improved energy services, particularly high quality fuels and cooking technology, directly impact the health of children. The most severe chronic exposure to airborne pollutants occurs among rural women and children from indoor sources due to biomass combustion in primitive, inefficient stoves. (Smith, 1993), (WEA, 2000). Long-term exposure to biomass smoke increases the risk of a child developing an acute respiratory infection by 100 to 400 per cent; about four to five million childhood deaths annually can be attributed to acute respiratory infections (WEC/FAO, 1999, p.26). The average under-five mortality for countries who derive less than 20 per cent of rural primary energy from biomass is 27.5 per 1,000 live births, rising to 173 per 1000 for countries deriving more than 80 per cent of primary energy from biomass (WEA, 2000, p.53]
10. Goal 5: Improved maternal health. As already noted, women are heavily impacted by bioenergy accessibility and the quality and quantity of household energy services, because of the large fraction of their labour devoted to energy provisioning and energy end-uses. The greater these arduous household chores, the less emphasis on women's education and the lower the age of marriage. Energy services can create rural livelihood opportunities that also help delay marriage age and can also reduce child labour requirements for water and fuelwood collection, thereby decreasing the rationale for large families. However, typical rural, developing world energy consumption patterns are not consistent with the prerequisites for a decline in fertility and consequent increases in maternal health (Batliwala and Reddy, 1994), (WEA, 2000).
11. Goal 6: Combatting major diseases. The first, second and third largest risk factors with respect to the global burden of disease are malnutrition, poor water and sanitation, and indoor air pollution respectively (WEA, 2000, p.70). High-quality energy services reduce all these risk factors through improved food security by intensifying agricultural productivity, increasing water accessibility and security, and reducing the exposure to indoor air pollutants from low-efficiency biomass combus-

tion. Furthermore rural electrification is also essential for basic disease prevention and treatment including refrigerated vaccines, intensive care and communication.

12. Goal 7: Ensuring environmental sustainability. Decentralized renewable energy for rural energy services is essential for climate protection. The alternative"business-as-usual" option—extending national power grids and expanding centralized power generation capacity using fossil fuels is not compatible with stabilized atmospheric CO_2 concentrations and risks catastrophic climate change (Nakicenovic *et al.*, 1998). Global sustainability includes the role that DREs play in promoting rural livelihoods. The majority of the world's population is still rural, geographically dispersed, and generally well-matched to the diffuse nature of renewable energy resources (WEC/FAO, 1999). Without the livelihood and agroecosystem opportunities that DREs promote, according to some observers, chronic rural under-development will be exacerbated, distress rural-urban migration will continue (Rajvanshi, 2002), (Gupta, 2003), the world will become increasingly urbanized and the opportunity of serving the majority of the world with renewable energy may be forever foreclosed.

Figure 1.10



1.7 Poverty and Climate Change

Having highlighted the linkages between environmental management and poverty alleviation, and the role of energy services with respect to both, we now turn to the related issue of poverty and climate change vulnerability in the context of how climate stresses exacerbate poverty by impairing the ecosystem services upon which the poor rely heavily.

Although the detailed geographic and temporal specification of future climate change impacts remains intractable to the current generation of general circulation models (GCMs), some general feature of climate change impacts can be deduced. Table 1.2 provides a partial list of expected twenty-first century climate impacts, their likelihood, and the expected livelihood outcome (IPCC, 2001a), which helps contextualize the extreme vulnerability of agrarian, natural-resource-dependent societies.

Indeed, one of the major insights from the IPCC's synthesis analysis of climate change impacts, adaptation and vulnerability is that world's poor are most heavily dependent on ecosystem services, and most vulnerable to deteriorating enviornmental conditions, worsened but not necessarily created by climate change (IISD, 2003).

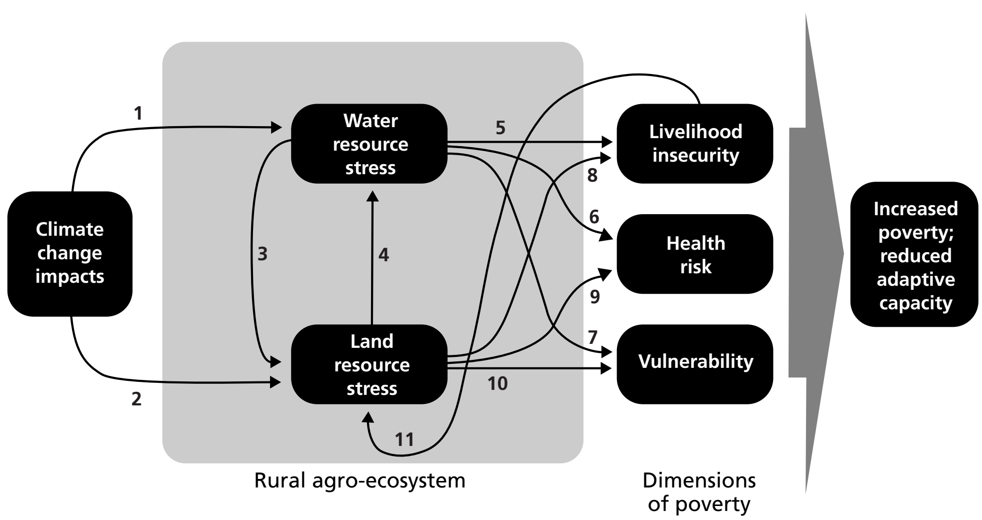
Table 1.2 Key climate change impacts on developing countries

Climate phenomenon	Climate impact
Higher maximum temperature (very likely)	• increased heat stress in livestock • increased risk of damage to a number of crops
Higher minimum temperatures (very likely)	• decreased risk of damage to a number of crops and increased risk to others • extended range of some pest and disease vectors
More intense precipitation events (very likely)	• increased flood, landslide and mudslide damage • increased soil erosion
Increased tropical cyclone intensity (likely – over some areas)	• increased risks to human life, risk of infectious disease epidemics, many others
	• increased damage go coastal ecosystems such as coral reefs and mangroves
Increased droughts and floods associated with El Niño events (likely – over some areas)	• decreased agricultural and rangeland productivity in drought and flood-prone regions
Increased Asian monsoon variability (likely)	• increased flood and drought magnitude and damages

Source: IPCC, 2001a

We interpret climate impacts in the context of a simplified agro-ecosystem model (Figure 1.11) and its relations to the dimensions of poverty as depicted in the World Bank's poverty-environment framework (recall Figure 1.8). Links 1 and 2 represent the varied temperature and hydrologic climate change impacts listed in Table 1.2 as they affect rural agro-ecosystems: increased risk of crop damage (1); increased flood, landslide and mudslide damage, increased soil erosion (1 and 2); decreased agricultural and rangeland productivity in drought and flood-prone regions (2); and increased flood and drought magnitude and damages (1).

Figure 1.11



These impacts can be magnified by a vicious cycle of agro-ecosystem breakdown (links 3 and 4 in Figure 1.11) that can be particularly acute in arid and semi-arid regions. Higher soil temperatures (1) increase evapo-transpiration and decrease soil moisture. Vegetative cover (natural or cultivated) becomes degraded and landscapes and watersheds are increasingly denuded (land resource stress). Run-off increases from degraded watersheds, soil moisture and groundwater reserves decrease (water resource stress), and the cycle of vegetation degradation and the loss of watershed integrity continues.

The poverty outcomes of climate change and agroecosystem stress are manifest as impaired ecosystems services affecting the livelihood, health and vulnerability dimensions of poverty. An ecosystem, according to the Millennium Ecosystem Assessment (MA), is a "spatially explicit unit of the earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries" (MA, 2003). Ecosystem services are the ecosystem attributes and processes that sustain and fulfill human life, and can be categorized as follows:

- *Provisioning:* The flow of natural resources to support human activity; food, water, biomass fuels, fiber, fodder, non-timber forest products.
- *Regulating:* Life-supporting functions such as water and air purification (forests), mitigation of floods and droughts (watersheds), detoxification and decomposition of wastes (bacteria), and generation and renewal of soil and soil fertility (micro-organisms).
- *Enriching:* The spiritual, aesthetic, scientific and social benefits derived from ecosystems (sacred groves, biodiversity reserves).

Poverty is exacerbated when climate change reduces the flow of ecosystem services. With respect to Figure 1.11, examples include:

- *Livelihood insecurity:* Reduced surface and groundwater availability, agricultural productivity from the loss of both regulating and provision ecosystem services (5 and 8).
- *Health risk:* Increased risk of water-borne disease and malnutrition as water and food provisioning services are degraded (6 and 9).
- *Vulnerability (to stresses and shocks including, but not limited to, climate change):* Increased risk of floods and droughts from the loss of watershed regulating services (7 and 11).

Land use management responses to livelihood insecurity (over-grazing, deforestation, agricultural land clearing, and unsustainable fuelwood consumption) can, in turn, exacerbate agroecosystem degradation leading to further loss of ecosystem services (11).

Precise definitions of poverty and adaptive capacity remain contentious (IPCC, 2001a), (World Bank, 2002), (Smit and Pilifosova, 2003) and that debate will not be resolved here. It is safe to conclude, however, that in the case of abjectly poor, resource-dependent communities, the underlying drivers of poverty—diminished livelihood opportunities, health risks and vulnerability—correlate with the social, economic and environmental components of adaptive capacity, implying that increased poverty leads to decreased adaptive capacity.

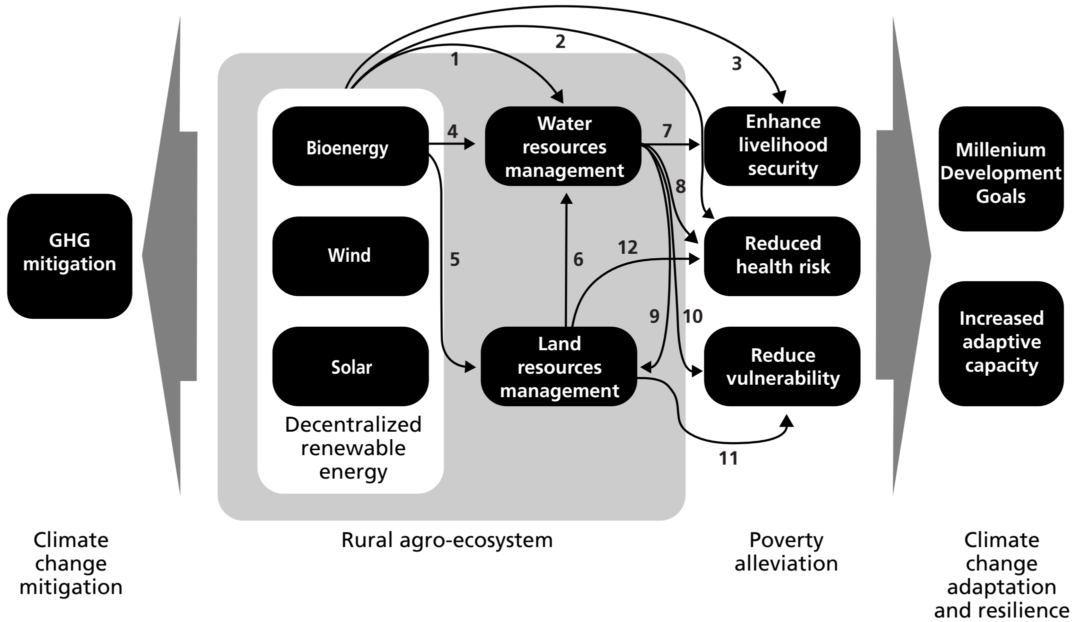
1.8 Decentralized Renewable Energy and the Adaptation-Mitigation Nexus

Decentralized renewable energy offers a constructive climate policy direction that provides simultaneous adaptation and mitigation benefits. The mitigation benefits are clear; DREs by definition are non-fossil fuel energy sources that have no permanent GHG emissions. The case for DRE as a climate adaptation strategy is less obvious but can be made with respect to the agroecosystem model that links ecosystem services to poverty alleviation, and builds on the linkages between energy services and poverty alleviation described in Figures 1.9 and 1.10. This conceptual model places poverty alleviation at the centre of adaptation (IISD, 2003).

Decentralized renewable energy, depicted in Figure 1.12 (as comprised of bioenergy, wind and/or solar), provides energy for irrigation pumping and post-harvest processing, which in turn provides new water resource management options and livelihood opportunities (1 and 3). Better lighting expands educational opportunities and livelihood options (3). Energy services also improve access to safe water and sanitation services, reduce exposure to indoor pollutants, and make possible access to refrigerated vaccines—all of which reduce health risks (2).

Bioenergy production affects both water and land resource management when implemented on a watershed basis and targeted towards the rehabilitation of degraded land (4 and 5), and can create a positive cycle of improving soil and water conservation with benefits to both land and water resources (6 and 9); these regulating ecosystem services enhance livelihood security by improving agricultural productivity and food security (7), and reduce vulnerability to floods and droughts (10 and 11). Improved accessibility to abundant bioenergy (a provisioning ecosystem service) is also a critical constituent of the well-being of poor women, reducing their labour burden and health risks (5 and 12).

Figure 1.12



Collectively these interactions contribute to poverty alleviation and increased adaptive capacity for climate change. In some specific cases, such as watershed-based bioenergy production and irrigation pumping, the link between DREs and climate change adaptation is obvious. The case, however, that DREs are generally an adaptive response to climate change can be made with respect to Holling's (2001) clarifying perspective on the nature of adaptive capacity, resilience and sustainable development.

Holling's notion of adaptive capacity includes the *resilience* of ecosystems to maintain their flow of services in the face of stress and shocks including, but not limited to, climate change. Adaptive capacity is also the resilience of communities to variability, and change (including but not limited to climate change) is a function of environmental, social and financial assets and the ongoing *capability* to transform these assets into human well-being. Adaptive capacity (or equivalently, *resilience*) in this formulation is the sum of assets and capabilities. Holling regards sustainable development as the natural outcome of policies that foster adaptive capacity. DREs can promote ecosystem resilience, a varied and strengthened asset base and diverse livelihood options, all of which foster adaptive capacity and further highlights the logic for including energy within the centrepiece strategy for achieving sustainable development, the WSSD Plan of Implementation.

Decentralized renewable energy is obviously not a panacea. It is, however, a coherent policy response with respect to both mitigation and adaptation objectives—largely because it respects the sustainable development aspirations of developing countries. As the International Energy Agency stated (IEA, 2002, p.6), "access to electricity and other modern energy services is a necessary but not sufficient condition for economic and social development." The sufficient condition is the *capability* of transforming the ecosystem services and livelihood opportunities created by access to energy into human well-being.

We next review DRE experiences in five countries and highlight features of those case studies with respect to the conceptual model of the mitigation-adaptation nexus developed in this chapter.

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Endnotes

1 Small-scale is defined as less that 15 MW maximum installed capacity or less than 15 GWh/year in energy efficiency gains.

2 Chlorofluorocarbons (CFCs) are another climate forcing agent, though indirectly through the destruction of stratospheric ozone. CFCs are regulated by another global multilateral environmental agreement (MEA), the highly successful 1987 Montreal Protocol on ozone-depleting substances.

3 The Annex I countries with GHG emissions quotas under Kyoto.

4 Annex II countries without emissions quotas who can host CDM projects under the Kyoto Protocol.

5 Ecosystem services are the benefits that people derive from ecosystems and comprise three major service categories; provisioning (goods produced or provided by ecosystems), regulating (benefits obtained from the regulation of ecosystem processes (water and air purification, mitigation of floods and droughts), and cultural (the non-material benefits obtained from ecosystems such as the social, aesthetic and spiritual enrichment derived from ecosystems) (UNEP, 2003).

2. Country Study: Argentina

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2.1 Introduction

Although Argentina is a developing country and has experienced high levels of unemployment and poverty in the last 14 years,[1] the energy system, particularly the electricity sector, has reached a relatively advanced stage. In 2001, the country had 25.3 gigawatts (GW) of installed electricity generation capacity; 57 per cent of installed capacity was fossil fuel-based (primarily natural gas); 38 per cent hydroelectric; and about four per cent was nuclear. Electricity generation (totalling 82.8 terawatt-hours in 2001), was distributed among thermal/fossil fuel (47 per cent); hydropower (45 per cent); and nuclear (seven per cent).[2] Argentina's per capita electricity consumption in 2000 was 2,190 kilowatt-hours—approximately equivalent to the world average and about 25 per cent of the OECD average (WEA, 2000, p.458).

By the end of the 1980s, Argentina already showed high electricity consumption and a high national electrification rate (nearly 92 per cent of the population had access to electricity) before power sector reforms intending to promote privatization began. The eight per cent of the population without access to electricity is overwhelmingly rural; about 30 per cent of the rural population remains unelectrified, mainly in isolated areas. The privatization process (which began in the 1990s), changed the whole context in which the electric systems functioned, but only produced marginal changes in the electricity access figures compared to the 1980s.

The privatization process occurred in the context of a major macroeconomic transformation of the Argentine economy that included deregulation in many sectors, an indiscriminate opening of the economy to international trade, and a great local currency overvaluation, financed mainly by capital inflows and a high external indebtedness. So, not only was the current accounts balance often in deficit (mainly because of the fluctuations in service payments of the external indebtedness), but the commercial account was in deficit as well. This fiscal situation proved to be absolutely unsustainable for a medium-income developing country like Argentina, and because of the financial crisis (mainly caused by the cut of financial capital inflows and the enormous drain of financial capital from local banks) in December 2001, the model finally collapsed as did the unrealistic parity of one Argentine peso equal to one U.S. dollar. The peso subsequently plunged in value by about 70 per cent. Argentina's economy continued to suffer in 2002. Argentina's GDP shrank by approximately 16 per cent during the first half of 2002, the largest economic contraction in the country's history.

Nowadays the macroeconomic context is absolutely different than in the 1990s and the impacts on the energy sector will be several: one of the most significant ones will be that the concession contracts will be revised to adjust to the new conditions of the economy.

In the reform process, the PERMER program (Renewable Energy Market Project for Rural Electricity) was developed. It is a World Bank and GEF-financed project to extend basic electricity services to 85,000 scattered consumers and 3,500 public services. By late 2002, the project had serious difficulties and came to a complete standstill with the cessation of all disbursements from the World Bank. By January 2003, however, funding had been re-established and now the project is again active. PERMER is a particularly innovative example of public-private partnership promoting sustainable rural development through energy provision. In this context, this chapter reviews the Argentine rural energy situation; the nature of climate change vulnerability in Argentina; and uses a case study from the PERMER project to illustrate how decentralized renewable energy projects promote sustainable development and increase adaptive capacity in rural Argentina.

2.2 Rural Energy-Poverty-Environment Context in Argentina

Biomass energy dependence and deforestation

There are very few recent comprehensive national studies of the rural energy situation in Argentina, although some representative and regional studies do exist. A study carried out by IDEE/FB[3] in 1991 estimated that there were about 730,000 Argentine households using firewood or charcoal for cooking and water or room heating purposes. The average firewood consumption in Argentina was about 3.2 tonnes/household/year. Firewood is, in most cases, freely obtained. Gatherers in each rural household are usually women and children, as the men generally work outside the house and may be absent for long periods to engage in seasonal harvesting activities.

Notwithstanding the above, attributing the responsibility of deforestation to the rural inhabitants that consume firewood lacks firm ground. While there might be isolated examples, these are not representative of the whole country. In fact, the visible causes of deforestation are the need to clear more land for agriculture (mainly for soy beans) and to meet the solvent demand of forestry products. In both cases, these are poor decisions about the production and extraction of natural resources that lead to the destruction of forests to create new land uses.

A rural household survey in Mendoza[4] (IDEE/FB, 1996) indicated that firewood, liquid fuels and electricity provided 46 per cent; 38 per cent; and 16 per cent of net energy demands respectively. According to polls carried out by the Energy Secretariat, firewood consumption in rural and also in sub-urban areas has intensified, replacing liquefied gas on account of the significant increase in the price of this fuel. In 1999 the production (extraction) of firewood was 3,636,229 tonnes—1,427,615 tonnes for firewood; 2,208,614 tonnes transformed into charcoal; consumption in the same year was 3,636,166 tonnes. with the small difference between production and consumption attributable to export.

Table 2.1 Firewood consumption (thousands of tonnes of oil equivalent)

Province	1970	1985
Corrientes	1.2	1.0
Chaco	36.8	16.5
Entre Ríos	8.7	16.3
Formosa	2.5	1.0
Misiones	28.1	33.6
Santa Fe	26.8	5.2

Source: IDEE/FB. 1987. Integral Energy Study of the Argentine Northeastern Region

Climate change vulnerability

The key climate change vulnerabilities of rural communities in Argentina are essentially related to the intensification of pre-existing ecological stresses. The most serious environmental problems in rural Argentina concern deforestation,[5] desertification (particularly in Patagonia) and erosion resulting from inadequate flood controls and improper land-use practices.[6] The climate change vulnerability of rural communities is thus a function of the severity of the existing ecological stresses, the magnitude of climate change impacts and the degree of dependence on the local natural resource base by the local population. Rural people without modern energy services and without access to grid electricity are typically those living in scattered, remote communities where the level of development is low and the level of natural resource dependence is high. Thus a typical developing world phenomenon re-appears: communities suffering most from energy deprivation are also those most vulnerable to climate change.

Subsistence production activities all depend on endowments of natural resources. Agriculture and horticulture require water resources for irrigation. Small-scale or subsistence cattle breeding in combination with the production of goat milk, hide and sheep wool also face climate and soil aridity limitations. Climate change will likely intensify stresses on the natural resource base by, for example, prolonging drought periods or increasing the number of floods and the consequent erosion of degraded land.[7] Vulnerability will be manifested as the marginalization of the subsistence activities itself (Ossandom and

Peixoto, 1996).[8] The following are some of the key features of isolated rural communities that exacerbate climate vulnerabilities:

- low technological level of current production, low sanitary and nutritional levels, inadequate plowing equipment and the need to adapt technologies to current production systems (or modify these systems);
- difficulty investing in irrigation, water collection and channelling;
- isolation and difficulty accessing urban centres;
- land-holding problems;
- insufficient size of the regional market for some products, falling demand of traditional products, commercialization problems and strong variations in the prices of some products; and
- low capacity for managing alternative crops, resulting in diversification difficulties.

These barriers clearly show the need to adapt in order to make the survival of rural communities viable. The basic climate change phenomena is the exacerbation of already-existing difficulties rather than the rise of new difficulties.

2.3 Decentralized Renewable Energy and Development

Overview

Access to modern energy services, like electricity, is not a development panacea; electricity does not necessarily directly reduce climate change vulnerabilities—although it can in some important cases. Poverty alleviation—mitigating some of the underlying characteristics of climate change vulnerability—does depend on access to energy services that are affordable, reliable and of high quality (FAO, 2002), (WSSD, 2002).[9] Energy is a determinant for poverty and development, supporting basic needs such as cooking, lighting, water supply, health care and communications, and it facilitates agricultural production, commerce and transportation. In rural areas of the developing world, introducing even small amounts of energy can have a positive multiplier effect in terms of increased income, education opportunities, health and food security (WEA, 2000). The catalytic role that energy plays in rural development is generally well understood by policy-makers and has historically provided the rationale for costly infrastructure projects like expanding the electricity grid to rural regions. Unfortunately, the prospects for grid expansion to the remaining unelectrified parts of Argentina are dim, particularly in light of the recent economic crisis. In this context, the implementation of DRE projects could be an important alternative for rural electrification.

The history of rural electrification in Argentina

Rural electrification began in Argentina with the National Rural Electrification Plans, intended to be implemented in three stages, however only two phases were completed: 1970–1975 and 1978–1981. Those two phases of rural electrification (and other projects outside them) succeeded in connecting 63,874 consumers through 73,250 km of new transmission and distribution lines. In 1981, 44 per cent of the rural households had electrical service, rising to 55 per cent[10] by 1989.

The plans were financed by the Inter-American Development Bank; 40 per cent in the first phase and by 50 per cent in the second. The remainder was jointly funded by the Energy Secretariat and the provinces through a cross-subsidy from urban consumers (the Special Hinterland Development Plan), the Bank of the Argentine Nation and from rural consumers. After the second phase, financial problems emerged, primarily related to:

- unnecessarily high technical standards resulting in high unit connection costs;
- high consultancy costs because of the stipulation that all contracts had to be awarded through a process of international bidding;

- high financing costs caused by the system used to update negative balances;[11] and
- lack of adequate legal framework to classify the activities "in the interest of the public."[12]

In 1987, revisions to the technical standards for rural electrification introduced by the Energy Secretariat (Resolution 696/87) encouraged further expansion of the national grid into rural areas. Rural electrification continued with financing from the Energy Secretariat, using resources from the Special Hinterland Development Plan (FEDEI), and to a lesser degree, cooperative resources and some provincial funds. The provincial companies played an active role at this stage, giving continuity to the expansion of the networks and to the supply to scattered rural settlements. The nature of the rural electrification process changed fundamentally, however, with deregulation of the Argentine power sector.

Deregulation of the Argentine power sector: Implications for DRE

Beginning in 1991, the government pursued an aggressive privatization program in tandem with the creation of an open electricity market, and attracted foreign investors and project partners. Power sector reform formally began in 1991 with Decree 634, which established a wholesale market and broke down the generation, transmission and distribution function chain. Law 24065 on Electricity Regulation was passed in 1992, which, among other things, does not allow electricity generators to be distributors at the same time, although it promotes horizontal competition among them.

During the initial stages of the sector's reform process, both the World Bank and the Inter-American Development Bank believed that the process itself and the privatization within the sector would bring about significant public benefits. The increase in the economic yield and efficiency of the utilities would result in positive externalities such as an improvement in the quality of the local air, higher-quality electricity services at lower wholesale and retail prices, and a rise in private investment on new generation capacity.[13] In the years immediately following the privatization of state-owned utilities (1993–94), many provinces, however, were reluctant to emulate the national reforms, as they received substantial income from the local public companies and, on the other hand, such companies represented convenient instruments for the development of sinecure policies and actions.

Aid offered by the World Bank and the Inter-American Development Bank to provincial governments included provisions imposed by the Argentine federal government that forbade multilateral aid to provinces that did not accept the national reform scheme, particularly the rate and price-setting structure for electricity services established for the concession of the distribution service.[14] Other conditions imposed by the federal government or the banks included the establishment of independent provincial regulators, the reform of the electricity supply structures and the downsizing of the provincial companies.[15] Provinces that depended more on federal funds or contributions from the multilateral banks generally adopted the federal model. Other provincial governments followed the same model but with significant adjustments, such as setting mandatory investment obligations for the new holders of the concessions on carrier services, or refusing to increase electricity prices in accordance with U.S. inflation. The conditions imposed by the banks and the federal government proved partially successful. Nevertheless, 10 of the 24 provinces—including Córdoba and Santa Fe, the most important ones after Buenos Aires—have not begun, or have interrupted the privatization of their electricity distribution services.

Privatization at the provincial level proved to be problematic for rural electrification and the expansion—and even maintenance of—electricity service to the more isolated rural settlements became extremely difficult. At the national level, access to electricity, which had reached more than 91 per cent prior to the reform, increased to 95 per cent in 2001. However, this increase was largely due to the normalization of previously-clandestine connections in urban and suburban areas rather than the expansion of electricity services in previously unconnected rural areas. Most of the inhabitants that remain without a connection are located in areas distant from the sub-transmission and distribution lines, being either fully isolated households, or in minor settlements where it is too costly to expand the transmission or distribution networks. Thirty per cent of the total rural population remains unconnected and is increasingly unlikely to be served by conventional distributors. The Argentine regulatory scheme, based on the price-cap principle, provides incentives for distributors to maximize their profitability through production efficiency increases. It therefore comes as no surprise that distributors have focused their investments on distribution networks in densely populated urban and suburban areas, where per capita rises in demand and the higher density have a favourable impact on the supply cost of electricity.

In 1995, the Energy Secretariat, responding to and anticipating the issue of undersupplied rural areas, announced a five-year program known as Electricity Supply to Isolated Rural Areas (PAEPRA). The program was devised to set concession contracts for carrying electricity to isolated settlements.[16] The Global Environment Fund (GEF) gave financial support for the development of the initial studies for the development of the chosen concept, which dealt with the market, the availability of the resource, and the analysis of service costs and rates. The Argentine government included this program for financing within the World Bank's network. This program was set to supply electricity for a mean scenario of 314,000 rural households (1.4 million people) and 6,000 community centres, with an expected power requirement of 17,000 KWp. One of the innovative aspects of the program was the introduction of decentralized renewable energy (DRE) technologies (solar, wind, hydro micro-turbines, etc.) in contrast to the diesel generation, the standard technology for remote power supply. The share of these technologies was estimated at 75 per cent solar photovoltaic; nine per cent wind; eight per cent hydro mini- and micro-turbines; and eight per cent diesel units for aggregate systems.[17] The program granted concessions for low density consumer areas to private electricity service providers for periods similar to those of standard electricity concessions. Recognizing that costs of DRE supply would be above the payment possibilities of the consumers, the program also provided subsidies to concession holders to ensure their profitability.

PAEPRA initially anticipated a total investment of 314 million pesos (at a parity of one to one with the U.S. dollar) with 147 million, 110 million and 57 million coming from consumer repayment, provincial subsidies and the Energy Secretariat respectively. Financing, however, did not materialize primarily because provincial governments were reluctant to subsidize concession holders, and potential investors showed little interest. Towards the end of 1999, the board of directors of the World Bank approved a loan to Argentina for US$30 million under a different name—Renewable Energy Project for Rural Electricity Markets (PERMER)—with an additional donation of US$10 million from the GEF to eliminate the existing barriers for the use of new technologies. PERMER was an attempt to breathe life into the moribund PAEPRA program, which had up to that point awarded concessions for isolated electricity systems in only two provinces—Salta and Jujuy.

The new World Bank/GEF funding would allow providing basic electricity services to some 85,000 scattered consumers and some 3,500 public services.[18] PERMER became the instrument for the provinces to use funds from the World Bank and GEF for their rural electrification plans. PERMER investment funds are available only to those provinces that have begun the reform of their electricity sectors (technical assistance funds under PERMER do not have this restriction). PERMER has the same basic objectives as PAEPRA: to develop sustainable electricity markets in scattered areas, supplied and partially financed by private concession holders using renewable resources and environmentally-clean technologies whenever possible. The long-term objective is to minimize government subsidies and create profitable rural energy enterprises.

PERMER's implementation was seriously undermined by the well-known financial and economic events in Argentina, particularly the significant devaluation of the Argentine currency.[19] Towards the end of the year, the project came to a complete standstill due to lack of disbursements from the World Bank, which were re-established by the end of January 2003. Amendments to the original agreement were necessary in light of the new economic realities faced by the project. Now the project has to recover its normal pace. The progress to date of one PERMER project, isolated electricity supply in Jujuy province is reviewed in the next section.

Case Study: Electricity supply to isolated settlements in the province of Jujuy[20]

Physical and socio-ecological context

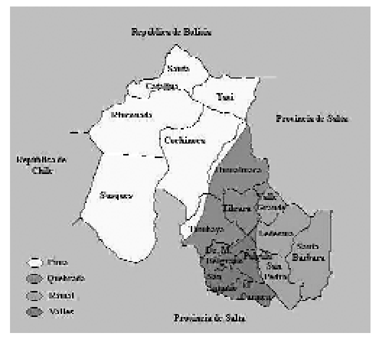
Jujuy is one of the 14 provinces that implemented the federally-mandated power sector reforms, and one of the first to access the subsidies available for decentralized electrification through the PERMER program. The former provincial power company, EJESDA,[21] which had already started a rural electrification program to supply scattered communities with diesel, solar and hydro generation systems, was awarded the first PERMER concession.

The province of Jujuy extends over 1.4 per cent of the total Argentine land mass with a total are of 53,219 km^2.

Figure 2.1 Jujuy in Argentina

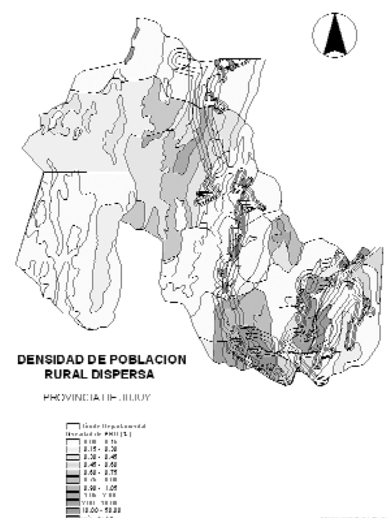
Source: http://www.globalstudentencounter.com/bsas/argentina1.htm

Figure 2.2 Provincial main areas



Source: General Office of Renewable Natural Resources of Jujuy, www.jujuy.gov.ar/ubicacion/index.htm

Figure 2.3 Density of scattered settlements



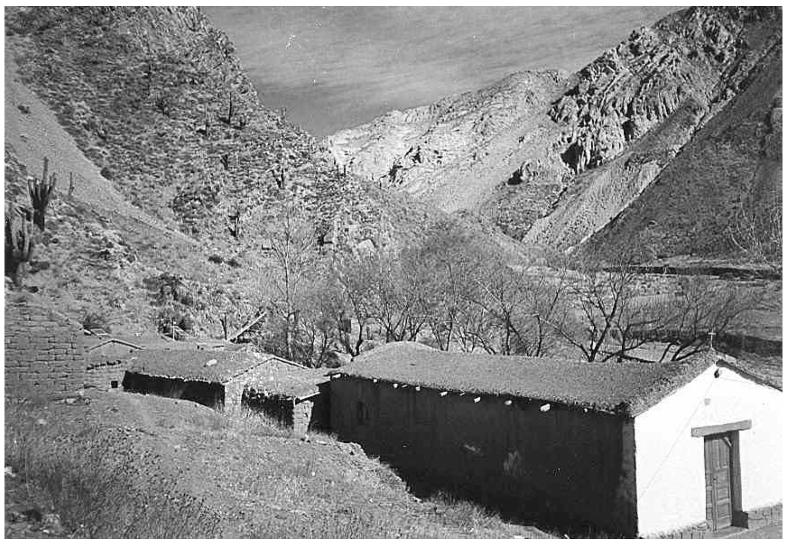
Source: Argentine Statistics and Censuses Institute (INDEC), National Population and Housing Census, 1991

Jujuy's relief is irregular with a mean elevation of 3,500 metres above sea level, Sierras and volcanic massifs dot the landscape. The Tropic of Capricorn line bisects the province, which varies climatically from cold, semi-arid to moist, semi-tropical.

Jujuy has also two hydrological systems, important stocks of certain minerals as well as hydrocarbons, as some of the main natural resources of the province. Regarding solar energy, approximately 4.5 kWh/m^2 per day of incident solar radiation are available throughout the province, one of the highest levels in the country.

Four distinct regions comprise Jujuy: (a) the valleys; (b) the mountain branch; (c) the mountain pass; and (d) the Puna (Figure 2.2). The last three, contain most of the isolated rural communities that were the targets of the PERMER project

Figure 2.4 Individual photovoltaic clients in Huachichocana in Tumbaya District



Source: Courtesy EJSEDSA

The valleys have a rainy climate, however the natural forest is in an advanced state of degradation because of continued over-exploitation; they are the most economically developed parts of the province.

The Puna region and the mountain branch are the least developed regions of the province. Puna has poor soils and a rocky, arid climate. The mountain branch has a varied climate, and poor soils primarily because of poor management and low levels of agricultural technology.

The mountain pass is a large oasis with a moist tropical climate and has the most important commercial agriculture activities: sugar, tobacco, tomatoes, peppers and citrus juices.

According to the 2001 National Census, about 15 per cent of Jujuy's population is rural, 61 per cent of which is considered scattered. Table 2.2 illustrates the drop in overall rural and scattered rural population from 1991 to 2001. Rural out-migration is generally driven by the lack of livelihood opportunities in these isolated communities.[22]

Table 2.2 Total, urban and rural population – Province of Jujuy

Year	Total urban population	Total rural population	Total rural grouped	Total rural scattered	Total population
1991	418,153	94,176	30,794	63,382	512,329
2001	521,561	89,923	34,872	55,051	611,484
Differences	103,408	(4,253)	4,078	(8,331)	99,155

Source: Guillermo y Lucas Gallo Mendoza. Aproximación a un Diagnostico Ambiental Expeditivo, con énfasis en el Sector Agropecuario Provincias. Junio/03

The isolated rural settlements have similar characteristics: generally high elevation;[23] long distances to markets; difficult access; and low socio-economic development associated with a subsistence economy. The main economic activities are cattle breeding, agriculture and handicraft weaving. Prospects for economic growth are low, because of the poor endowments of natural resources. The very high reliance on an impoverished natural resource base makes these communities vulnerable to the intensified ecological stresses from climate change, such as increasingly frequent floods and droughts.

Firewood is the main energy source for the scattered rural populace, especially for cooking and heating purposes.[24] Table 2.3 shows, qualitatively, the energy consumption matrix for most rural families in the area. Although, firewood is the primary energy source for isolated rural communities, the high rate of deforestation in the province is primarily attributable to land clearing for subsistence agriculture.[25, 26, 27] Firewood consumption is not the causal factor driving deforestation—but it is however an important indicator of the low development level in those communities.

Table 2.3 Estimated qualitative use and source matrix

Source	Use	Intensity
Firewood	Cooking, heating	High
Kerosene	Lighting	Medium
Liquefied gas	Lighting, some cooking	Low
Batteries	Lighting, social communication	Low
Candles	Lighting	Low

Rural energy supply in Jujuy province

The Argentine wholesale electricity market meets most of the urban and suburban electricity demand in Jujuy. Local generation supplies only 11 per cent of the province's energy demand, which in 2001 rose to 510 GWh,[28] with over 120,000 consumers. The remote rural market in 2001 demanded a little over one GWh, with over 4,000 consumers. EJESDA, assumed the mandate of the state provincial utility - electrification of isolated rural communities with diesel, solar and hydro generation systems[29] and was awarded the concession for this service within the framework of the PERMER program. EJESDA's concession included service to communities with and without autonomous mini-grid networks. The former are generally supplied with diesel-based, micro-hydraulic or hybrid renewable energy systems, whereas in the case of the latter, electrification takes place through individual photovoltaic systems in individual homes and schools. The main objective in electrifying the isolated settlements was to provide electricity for basic development; lighting for education, communication and livelihoods promotion.

According to surveys[30] carried out in some of the remote communities, most families spend about $9 to $21 per month to light their homes with kerosene burners, lanterns and wood-burning kitchen ranges. Battery-operated radios provide communication with the rest of the world, but at considerable further expense. The relatively high existing household expenditures on lighting and communication means that at least part of the cost of providing electricity could be defrayed by the end-users. Interest in electrification is high as most householders recognize that if the marginal cost of lighting was significantly reduced, more time could be devoted to income-generating tasks that required lighting such as handicraft weaving. Additionally, householders would benefit from the reduced exposure to combustion by-products from diesel, kerosene, liquefied gas and candles.[31]

Despite the interest and recognized benefits of electrification, it was also clear that many isolated households could not pay the full cost of photovoltaic electrification. Setting the appropriate tariff became a major implementation hurdle. After much negotiation between the provincial government, the company and the community representatives, a subsidy system was established. The subsidy system essentially confirms that providing basic electrification in these remote communities scattered electricity market must still be subsidized as it is intrinsically unprofitable due to the scale diseconomies and the small per capita income of the consumers. The concession contract[32] therefore established the subsidy amount for individual consumers at $600 for installation of the 100 Wp unit. The consumer pays $60, while the province subsidizes the remaining $540 through the PERMER project. The installation charge covers the capital cost, and recurring monthly charges to the end-user provide a return on investment to the concession holder.

The monthly rate structure as a function of the levels of service, along with the number of connections at the various service levels, is shown in the Table 2.4.

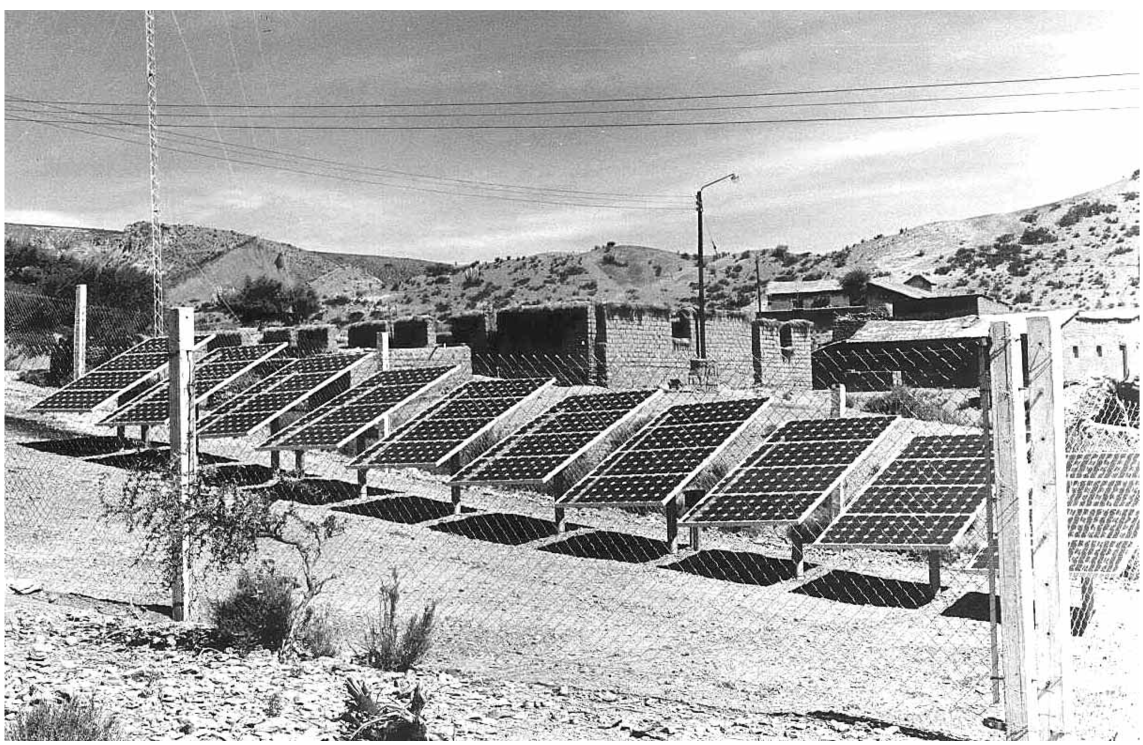
Table 2.4 Consumption, consumers and payment levels

Service type (Wh/day)	Number of potential consumers	Monthly rate payment ($)
125	361	3
175	516	5
250	688	10
375	138	17
500	17	25

The rate structure applied to both household connection and community services (clinics and schools). EJESDA identified a client base of 1,720 households and 34 community services.[33]

At least 12 per cent of the families surveyed did not accept the service or could not pay this tariff. Another 13 per cent of the potential household consumers could not be serviced due to their extreme isolation. Currently EJSEDSA[34] supplies 4,054 rural clients, 2,146 of which are served through rural mini-grids[35] based on diesel, micro-hydro and hybrid renewable energy systems. 1,908 rural clients are served with individual photovoltaic. Individual households, schools (3,500 students), 45 health centres, 37 community centres, and public services such as street lighting comprise this market. Figure 2.5 shows a photovoltaic mini-grid system in the village of La Ciénaga. Figure 2.6 and 2.7 show individual household PV installations in the village of San Juan de Quillaques and in Santuario de Tres Pozos region.

Figure 2.5 Electrified community network in La Ciénaga, Santa Catalina district, Jujuy



Source: Courtesy EJSEDSA

Figure 2.6 Individual Clients in San Juan of Quillaques in Susques District

Source: Courtesy EJSEDSA

Figure 2.7 Electrified household in Santuario de Tres Pozos, Cochinoca District

Source: Courtesy EJSEDSA

Figure 2.8 EJSEDSA car in the Large Salinas in Susques Districts

Source: Courtesy EJSEDSA

One of the major reasons for the success of the project[36] was the comprehensive development approach that EJEDSA practised, which involved visits to all remote and inhospitable areas with households (Figure 2.8) to understand the social, economic and cultural characteristics of their development needs.[37] The professional staff involved in the project came from the region. The key features of rural energy deprivation are: its constraint on economic development; the paucity of communication; the negative health impacts of low-quality lighting and pollutant exposure; and the high household expenditure on energy services, were all well known to the project designers.[38]

Other features of the comprehensive development approach practised by EJEDSA that PERMER project funding facilitated include micro-credit financing and medical student exchanges. EJEDSAlso partnered with a local women's development NGO, the Association Warmi Sayajsunqo of Abra Pampa (AWSAP), to form a local micro-credit institution by providing an endowment of US$10,000. This seed money was in turn distributed among 10 producers who bought wire, seeds and high-quality reproductive livestock. Returns from these investments flowed to other communities. AWSAP is now active in 54 communities and has 10,000 members. The company also implemented an exchange program for medical students to visit and attend to the health problems villagers and also donated: education and handicraft materials, clothes and medicines.[39]

EJEDSA also recognized the social significance of schools, which serve as community centres and hostels. Schools now host community social events in the evening after the daily labours. Electric lighting made it possible. All the schools have access to electronic information services including satellite TV. Another frequently mentioned benefit of electrification has been the improved public security associated with street lighting.

Figure 2.9 Electrified school in San Miguel de Colorados, Tumbaya district

Source: Courtesy EJEDSA

Figure 2.10 Street lighting in San Juan de Quillaques, Susques district

Source: Courtesy EJEDSA

The mitigation-adaptation nexus

The total GHG mitigation benefit accruing to the project is estimated as approximately 200 tonnes CO_2/year,[40] for all individual household consumers. Another major environmental benefit of displacing solid and liquid fuels with renewable energy is the decreased health risk by reducing exposure to indoor pollution, as well as the reduced fire risk particularly for children. Although the full electrification cost is about $25 per household per month, people pay only $3 per month. Compared to pre-electrification costs ($9 to $21), this is a significant benefit. The lasting economic benefits to the community, however, are the social and livelihood opportunities that this more efficient, cleaner and more versatile energy source provides, many of which have been realized through EJEDSA's comprehensive community development approach.[41]

The EJEDSA approach went beyond a merely sectoral and technical intervention program and included community development programs to create livelihood and cultural opportunities that complemented electrification. In doing so, the project increased the people's adaptive capacity to cope with social, economic and environmental stress *including*, but not limited to, climate change. The EJEDSA-Jujuy example illustrates that rural electrification based on decentralized renewable energy is not always a direct climate adaptation strategy, but the livelihood and social opportunities that electrification allows are extremely important in building adaptive capacity.

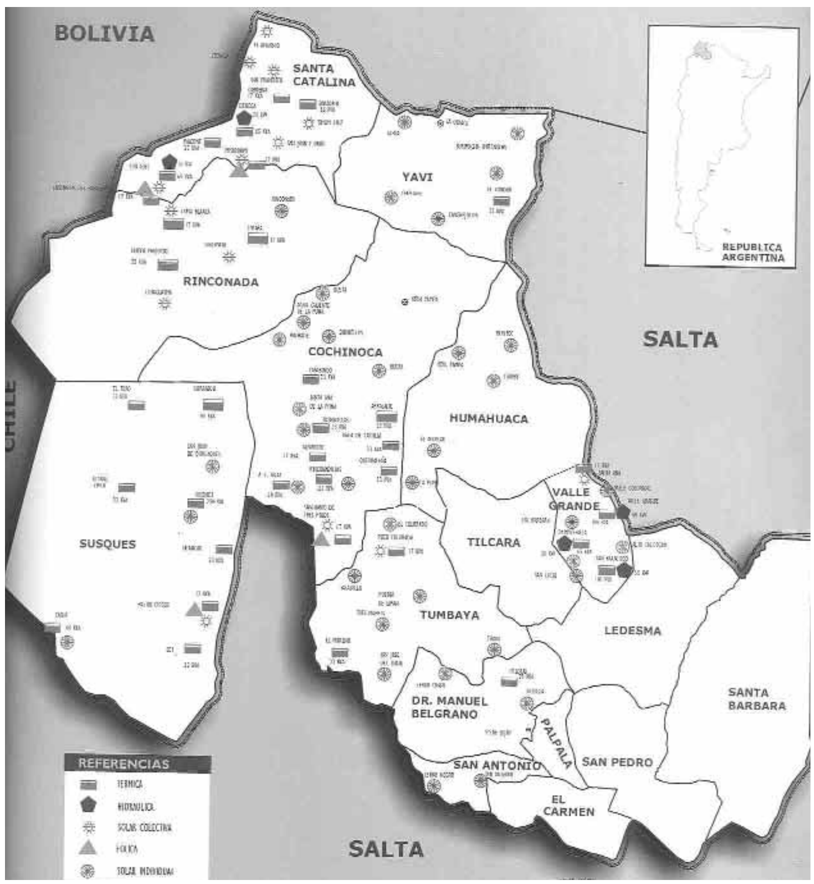


Figure 2.11 Location of DRE projects in Jujuy

Source: EJEDSA, "Scattered but United," 2001, op.cit.

Outstanding issues and lessons learned

The major climate change vulnerability in the remote communities of Jujuy comes from intensified ecological stress on an already degraded natural resource base. Fuelwood extraction is not the major cause of ecological stress, and the fuelwood supply is not necessarily threatened by climate change. The major cause of ecological stress—that will intensify climate change vulnerability—is deforestation for land-use change for expanded agriculture activities. The high use of firewood is an indicator of poverty and subsistent agricultural practice, and reflects a natural resource-dependent economy inherently vulnerable to climate change.

The DRE projects have provided many socio-economic benefits, and have increased community adaptive capacity to future stresses *including* climate change. The relative success of the project (88 per cent uptake among potential clients), can be attributed as much to EJEDSA's implementation program as to the inherent attractiveness of the technology. EJEDSA approached the project as an integrated community development effort, one critical and catalytic element of which was the introduction of DRE technology that made possible new social and livelihood opportunities. Project beneficiaries enjoyed significant improvement in the quality of life with the availability of high quality lighting, increasing reading and scholastic opportunities, communication, music, handicrafts, social activities and security in the streets, and improving access to diversified electronic media.

Among the key project concerns is overall economic sustainability. For example, the cost of bulb (between $40–60 every three years) is the user's responsibility and no subsidies exists to defray that cost. The project is possible because of large state subsidies. Expanding the agricultural livelihood opportunities of the community by introducing irrigation, soil management, reforestation, looms and good seeds would allow people to pay for electric services without subsidies; further development will, however require much more energy supply (particularly for irrigation and agricultural post-processing) and more extension service. The important DRE policy issue that Argentina must in turn address is if CDM investment opportunities can be targeted towards the institutions capable of the integrated rural development required to build adaptive capacity and seize the opportunities that DREs can provide.

Endnotes

1 Nevertheless, Argentina still shows the highest Human Development Index of all Latin American Countries.

2 Secretaria de Energia "Informe Del Sector Electrico Año 2001" http://energia.mecon.ar/home_elec.asp

3 IDEE/FB, 1991."Analysis of the forestry biomass share in the production of energy in Latin America, Latin American Dendroenergy Technical Cooperation Network," Itajubá, Brazil.

4 Mendoza is a medium-level development province. The income per inhabitant is 65 per cent of the national average.

5 Related to clear land for agriculture and to meet the demand of forestry products, but restricted to certain particular areas.

6 Information from http://www.jica.go.jp/english/global/env/profiles/pdf/06.pdf

7 The following are other geographical characteristics that are evidence climate vulnerability:

- Scarce rainfall, concentrated in spring and summer (Arid brush: Santiago del Estero).
- The mentioned climate imbalance: great droughts/repeated floods (Wet Chaco: Formosa).
- Ecosystem fragility, deterioration of natural resources due to pronounced deforestation resulting from the change in soil use, intensity of precipitation, and relief, pronounced slopes (ArgentineMesopotamia: Misiones),
- Advanced process of desertification in the Patagonian plateau due to excess pasturing in natural pasturelands (Wool-producing Patagonia).

8 Ossandom, D. and Peixoto C., Productores Minifundistas y Desarrollo Tecnológico, PROINDER, Working Paper No. 1, FAO, FAO – World Bank Cooperation Program, Buenos Aires, 1996.

9 See SD dimensions August 2002. The Role of Energy in Sustainable Development: Rio, Johannesburg and beyond.

10 Regional Electricity Integration Commission (CIER), 1989. "25 years. History, operation and work of the Commission. Historical background of the public electricity service in member nations."

11 High interest rates for the project's financing discouraged the farmers. Those future users had low incomes and difficulties with climate adversities, so the payment of the quotas and their interest were always delayed. The socio-economic characteristics of rural population were not totally taken into account in the project development process and also an adequate legal framework was absent.

12 See the previous footnote. Because of the lack of a appropriate legal framework, the protection of the different rights of the users were not contemplated in any place.

13 Bouille D., Dubrovsky H. and Maurer C., 2003 "The Argentine Electricity Sector: A market-oriented reform," WRI/FB, Buenos Aires.

14 Pistonesi, H., 2000. "Argentine Electric System: Performance after the reform" IDEE/FB, Buenos Aires, Bariloche Foundation.

15 Bouille D., Dubrovsky H. and Maurer C., 2003. *op. cit*.

16 Energy Secretariat, 2001. "Electricity supply to the Argentine Scattered Rural Population," http://energia.mecon.gov.ar

17 Energy Secretariat, "Informe de Prospectiva 1999," Section 9, 9.2. http://energia.mecon.gov.ar

18 In this section we interviewed: Alicia Baragatti and Mónica Servant (National Director of Promotion) and Aldo Fabris (Consultant).

19 Project Coordination Unit, PERMER Project, Report on the Present Situation, March 2003.

20 In this Section we Interview: Carlos Arias and Ruben Orellana of EJSEDSA.

21 This company was created specifically to supply the rural market.

22 Argentine Statistics and Censuses Institute (INDEC)," 1991 and 2001. National Population and Housing Censuses.

23 Arias C. (EJSEDSA), Torrellas R. (EJSEDSA), Quispe Reyes M. (EJE SA), 2002. "The regulation of the electricity market scattered throughout the province of Jujuy, Argentina (experiences from the 1996–2001 period)."

24 The statement is supported by the survey of the information sources mentioned in the present study.

25 Ministry of Economy, Agriculture Secretariat. 2001. "Forestry Annual Report/Provincial extraction products."

26 Source: Esper Norma, 2001. "Forest Fuel Case Study." UE/FAO (GCP/RLA/133/EC), Argentina.

27 Editorial Clarín, 1995. "Mi país, la Argentina." (general data on all Argentine provinces).

28 Ministry of Economy, Energy Secretariat, 2002. "2001 Report from the electricity sector, provisional."

29 Ministry of Economy, Energy Secretariat, 2001, *op. cit*.

30 Argelia Combetto. 2000. "Structure of the Scattered Electricity Market of the Province of Jujuy" PERMER Coordination Unit

31 Frigerio, Alicia, 1998. "Environmental aspects of the program to supply electricity to the scattered Argentine rural population," Energy Secretariat, Renewable Energy in Rural Markets Project (PERMER). Buenos Aires, Argentina.

32 Rates are reviewed every two years through public audits.

33 Held in 2000. A study is being presently carried out on the potential production uses of electricity in the scattered electricity market (fruit and vegetable drying, water pumping, small computer workshops, etc.).

34 EJEDSA. "The secret energy." 2003.

35 1,185 through thermal, 539 through hydro, and 422 through photovoltaic systems (in 7 cases supported with diesel units and in 4 with wind chargers).

36 For more information: Source: EJEDSA, 2001, *op. cit*.

37 In this direction, they made an important and detailed study of the situation and needs of each small village to be supplied.

38 Long distances and nomadic culture are important difficulties for the company. People move between two or more points with their animals and agricultural products, so any time the house with the generator is isolated the theft of this equipment is attractive.

39 For more information: Source: EJEDSA, 2001, *op. cit*.

40 Emission Coefficients KE: 2.34 kgCO_2/litre and LGP 3.02 kg CO_2/litre, and 1908 individual generation with an estimation of with 3 liters of kerosene an 0.5 kg LPG per month. Lic. Alicia Frigerio Secretaría de Energía, Proyecto de Energías Renovables en Mercados Rurales, PERMER 5/11/98, Buenos Aires, Argentina.

41 SIEMPRO http://www.siempro.gov.ar/informes/integrales/informes_integrales.htm

3. Country Study: Bangladesh

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3.1 Introduction

Bangladesh is a densely populated (130 million people living in 144,000 sq. kms.) agricultural country. In the year 2000, its per capita income was US$350 and per capita commercial energy consumption was 120 tonnes oil equivalent (toe). Rural Bangladesh remains the backbone of economic development of the country. The agriculture sector contributes more than 30 per cent to the GDP and employs 60 per cent of the total workforce. Approximately three-quarters of the population lives in the villages and are heavily dependent on agriculture.

Table 3.1 provides a snapshot of energy consumption in the year 1999–2000. As can be seen, even at the end of the twentieth century biomass still provides 53 per cent of the total energy. Less than 30 per cent of households have electricity and approximately four per cent of households have natural gas supply. More than 80 per cent of the total and 95 per cent of the rural households use biomass to cook. It is worth pointing out that the data on biomass are very sketchy. The last comprehensive survey and compilation of data was conducted in 1982. The data reported for any year since then is a projection using a model developed in 1985 under a project called Bangladesh Energy Planning Project. Renewable energy other than biomass and hydro constitute a very small percentage of the total energy consumption. This of course excludes the use of sunlight for various drying operations by households, commercial establishments and industrial units. The transition to modern fuels like kerosene, Liquid Propane Gas (LPG) and natural gas is taking place at an extremely slow pace and is driven predominantly by increasing prosperity. It is, therefore, safe to assume that most rural households will continue to cook using biomass for a long time to come since per capita income is growing at a very slow rate.

Table 3.1 Energy consumption in the year 1999–2000 (million GJ)

Sector	Coal	Oil	Natural gas	Total commercial	Biomass
Power generation		11.90	147.31	159.21	
Residential		26.02	29.36	55.38	440
Commercial	1.35	1.27	3.81	6.43	2
Industrial	25.00	11.43	40.62	64.20	118
Transport		62.35		62.35	
Agriculture/others		24.57		24.57	
Non-energy use (urea fertilizer)			84.00	84.00	
Losses and own use		1.86	23.91	25.77	
Total	26.40	139.40	329.00	494.80	560

Note: In addition, 1,027 GWh of hydro electricity was generated. The coal figures are industry estimates.

Source: Compiled by the authors from various sources but mainly from BBS (2002)

3.2 Energy-Poverty-Environment (Rural) Context

A. Rural energy situation and biomass dependency

Overview of energy availability

The Rural Electrification Board (REB) network covers approximately 40 per cent of rural Bangladesh, and within the grid-covered area only 40 per cent households have electricity because most households cannot afford the connection charge. Table 3.2 provides an overview of the level of rural energy consumption.

Table 3.2 Level of rural energy consumption for the financial year 1999–2000

	Amount	Cooking	Lighting	Commercial cooking	Industries
Biomass	45 m tonnes/560 m GJ	> 95%	–	80%	60%
Kerosene/diesel (Diesel)	0.64 m tonnes/30 m GJ	3–4%	75–80%	8%	12%
LPG	.05 m tonnes/1 m GJ	< 1%	< 0.5%	< 4%	< 1%
Electricity	3000 GWh	< 0.5%	20–25%	< 1%	12%
Coal	1.4 m tonnes/26.4 m GJ	< 0.5%	–	8%	15%

Source: Compiled by the authors from various sources but mainly from BBS (2002)

Energy sources and biomass dependency

It is very difficult to put an exact figure on the extent of biomass dependency, but it is safe to assume that the overwhelming number of rural households (> 95 per cent) use biomass for cooking. Only wealthy households use kerosene and LPG but even then only as supplementary fuel. Among the biomass users there is a progression from fuelwood to agricultural wastes and cow dung with decreasing income level. It is interesting to note that rural affluent people do not buy their fuel because it is collected from their own property. The rural middle class are the people who access their cooking fuel from the market. Accessing fuelwood from the market decreases with decreasing household income level. The middle and lower middle-income households do not access any significant amount of biomass from their own property because homestead forests are devoted to providing shade, protection from winds and to supply fruits. The poorer households generally gather biomass fuel from a variety of sources including from common property and agricultural fields.

In the late 1970s and early 1980s, there was a prediction that in the not too distant future there would be severe biomass fuel shortage, but even after 20 years such a shortage is not clearly in sight. Energy analysts apparently underestimated plant growth and the regenerative capacity of tropical forests. However, it must be admitted that many designated forests are deforested and that every year it is becoming harder and harder for households to collect the desired quantity of biomass. Opinions differ on how people have coped in an arena of dwindling supply of biomass fuels and increasing population, but one thing is certain—that the improved cookstoves that were being promoted to address the projected crisis have not played any role. During the last 20 years, crop production has increased significantly making larger quantity of agricultural wastes available. However, this trend is on the decline because increase in crop production is slowing down and the high-yielding variety of rice that is now widely grown produces much less waste. One thing that has probably played a big role in tackling the looming disaster is social forestry. It may be that the biomass crisis prediction of the seventies was premature, and that the doomsday has only been postponed due to a variety of measures adopted by the biomass users. No study exists which can convincingly answer the question why the biomass shortage hasn't happened, and the coping techniques adopted by households have been studied only sketchily.

Very crude and inefficient technologies and appliances are used for cooking and in rural industries. Even three-stone cookstoves are used in many rural areas. Efforts of some government research institutions to popularize improved biomass cookstoves have not been successful for a number of reasons including the lack of proper initiatives to disseminate the technology and failure to educate rural people about the benefits of the efficient devices.

Rural electrification status and prospects

The Rural Electrification Board (REB), a statutory government body, was created in 1977 to provide electricity to rural areas. The REB promotes rural distribution of electricity through consumer cooperatives known as Palli Bidyut Samity (PBS). In September 1995, the Government of Bangladesh announced its National Energy Policy (GoB, 1996). This Policy includes the following documents: Non-Renewable Energy Policy, Petroleum Policy, Renewable and Rural Energy Policy, Power Policy and Rural Electrification Policy. Among these, the Government is actively supporting the Rural Electrification Policy through the Rural Electrification Board. Specific policy issues encompass:

- demand estimation and planning (including area of coverage within a PBS);
- prioritizing grid extension on the basis of techno-economic considerations;
- managing demand, load factor and capacity utilization, and also encouraging efficient use of electricity by domestic consumers;
- planning separate power plants to support the REB network;
- rationalization of tariff structures and utility areas; and
- strengthening REB's institutional status by availing the services of other government organizations involved in rural development for diversification of economic activities and rural industrialization.

In addition to the main broad policies, the government from time to time formulates policies targeted to achieve specific goals. Of relevance to DRE projects is the "Policy Guideline for Small Power Plant in Private Sector" for establishing mini-power plants with capacities up to 10 MW in the private sector.

It is the stated policy of the government to bring all villages under the electricity network. Tables 3.3 and 3.4 summarize the status of rural electrification in Bangladesh.

Table 3.3 Status of rural electrification (June, 2003)

No. of PBS	Km of line energized	No. of villages electrified	No. of thana included	Consumer connected (million)	Estimated cost of the project (million Taka)
67	156,000	38,500	410	4.7	40,000

Source: REB (2003)

Table 3.4 Energy consumption and consumers for the financial year 2001–2002

Sl. No.	Consumer category	Annual consumption		Consumer connected	
		GWh	%	Number (million)	%
1.	Domestic	1,660	43.00	3.36	84.00
2.	Commercial	219	6.00	0.45	11.25
3.	Industry	1,649	42.00	0.07	1.75
4.	Irrigation	357	8.75	0.10	2.50
5.	Others	10	0.25	0.01	0.50
	Total	3,895	100.00	3.99	100.00

Source: REB (2003)

Status of energy reform including power sector

Even though the energy sector reforms started nearly a decade ago, the process has not gone far enough to address any of the significant issues plaguing the sector. The reforms in the power sector were predominantly aimed at reducing the alarming system loss, which stood at over 40 per cent in the early 1990s. However, it is fair to say that the reforms have halted the slide in the performance of the power sector as evidenced by the nearly 10 percentage point improvement in the system loss. On the generation side, the introduction of the Independent Power Producers (IPP) have made power more readily available, but the inability of the utilities to pay the IPPs in time is a major concern.

Rural electrification has always been in the election manifesto of all political parties, and despite the severe resource constraints, all governments have pursued it seriously. The government aims to electrify all villages by 2020. Experts believe that, given the inaccessibility of many places, 100 per cent coverage is not economically feasible, and a more realistic figure is 80 per cent. The percentage of electrified households, however, is another matter, and unless rural poverty is tackled, less than 50 per cent of the households in electrified villages will be able to enjoy the fruits of the government's electrification program. The definition of what constitutes an "electrified village" is fairly arbitrary. The utility considers a village electrified if a trunk line and few feeder lines traverse the village. If a household is within 200 yards of the utility line, a connection is given to a household free of charge. Otherwise, households have to pay for the connection charge, which can be significant.

The present policies do allow small-scale generation (< 10 MW), and local IPPs are stepping in to supply electricity to REB. The fuel used by these IPPs is natural gas, but there is no ban on using renewable sources. A renewable energy policy, where wide-ranging incentives are proposed, is awaiting approval, but whether those recommendations will be implemented is not clear. Import of solar PV panels and wind turbines has been made tax-free. The support for DREs in the new policy will probably be provided in the form of a tax waiver on imported machinery but support in the form of a higher unit purchase price of electricity is unlikely to be granted.

The government has not given permission to any private operator to distribute and sell electricity in rural areas probably because no proposals have been submitted. The country is expected to have an independent Energy Regulatory Commission (ERC) very soon. Once the ERC starts functioning, one can expect that it would be a lot easier to convince them instead of the government of the beneficial aspects of DRE technologies with the result that laws and regulations to effectively promote DRE technologies can be enacted.

DRE promoters are awaiting the Renewable Energy Policy, which is expected to provide wide-ranging incentives to renewable energy technologies. If DRE technologies can deliver electricity at a competitive price, REB will welcome it. It is unlikely that in support of DRE generation, REB will be willing to buy electricity at rates higher than what is otherwise available. High efficiency combined cycle natural gas generation has made electricity prices extremely low in Bangladesh. It is very difficult in such circumstances for any renewable energy technology to compete.

B. Poverty and environmental implications of the rural energy situation

Livelihood opportunities of the rural poor

Access to electricity is one of the lowest in the world with only 30 per cent of the total population being covered. The efforts over the last 20 years to bring about 35 per cent of the rural land area under grid coverage by the Rural Electrification Board has made significant changes to the lives of those who have been able to afford a connection. A recent study's (NRECA, 2002) findings of the impact of rural electrification give a good indication of what is missing in the lives of a "dark" household:

- 93.7 per cent of the electrified households reported a decrease in fuel cost;
- 78.2 per cent of households reported an increase in working hours;
- 62 per cent reported an increase in household income;
- 81 per cent reported an increase in reading;
- 93.7 per cent reported an increase in childrens' study time;
- 92 per cent reported an increase in amusement as well as standard of living; and
- 94.7 per cent reported improvement in security.

These findings clearly demonstrate the hugely uplifting effect of rural electrification. Thus the development benefits of reaching electricity to the poor contribute significantly to increased adaptive capacity.

Traditional rural industries/activities like brick making, rice parboiling, smithies, pottery, making of molasses and edible oil and other miscellaneous activities, consume over 10 million tonnes of biomass annually, most of which is firewood. Supply shortage has reduced firewood's share of the total biomass fuel consumed for all activities from 63 per cent in 1981 to 22 per cent in 1990 (Biswas, 2001), and in 2003 it stands at 15 to 18 per cent. The price of fuelwood has gone up from Taka 0.3/kg in 1981 to Taka 2.5/kg in 2003, thus registering nearly an eight-time increase whereas the real value of the Taka has decreased only about four times. Traditionally, the rural upper and middle classes have always used fuelwood as their cooking fuel. The lower middle class uses a 50-50 combination of fuelwood and low-grade fuels. The proportion of low-grade fuel such as animal waste and agricultural residue is increasing every year. The buying and selling of fuels for cooking in rural areas is very limited. Ahmed *et al.* (1986) has found that only a small section of large farmers, owner-cultivators and landless labourers buy fuels, and that the last two categories buy dung sticks and tree branches mostly during the rainy season. In the last 20 years, the rural people have seen their real incomes being eroded away and it is easy to estimate that the cooking costs for many lower income households during the rainy months, when nearly all their cooking fuel has to be purchased, may reach 30 to 50 per cent of their monthly income.

From the preceding discussion, an important linkage can be established between rural electrification and adaptation to climate change. The NRECA (2002) study indicates that electrification decreases fuel costs and increases household income by increasing income generation activities. It can thus be expected that households, by moving away from low-grade fuels like crop residue and dung, will contribute to increasing the soil organic content. Loss of soil organic content makes land more vulnerable to desiccation and erosion leading to land degradation. Since loss of soil organic content makes the land more vulnerable to climate change (drought and flooding), the use of the DRE-based rural electrification can lead to decreased soil stress and decreased climate change vulnerability.

Environmental implications of the existing rural energy situation

Where a good soil should have more than 3.5 per cent organic matter content, most of the soils in Bangladesh have less than 1.7 per cent organic matter. In some areas, it is less than one per cent (BARC, 1999—as reported in FAO, 2003). Although the principal reason for such degradation is improper, low and unbalanced replenishment of plant nutrients to soil, declining organic recycling is also a significant contributor. The widespread use of crop residue as fuel and fodder, and the large extraction of even cow dung from the land have resulted in a decrease in soil organic matter content. Intensive cultivation has reduced the organic matter content from two per cent to one per cent in the last 20 years (FAO, 2003) in most of the medium to high highlands of the country. The decreasing yields from year to year in many areas of the country have made farmers aware of the land degradation problem. Even though the country is suffering from only low to moderate degrees of degradation, many areas may become irreversibly degraded in the not too distant future.

Deforestation of the traditional forests is increasing. Chittagong Hill Tracts, a hilly forest area in the southeast of the country, is being denuded due to traditional shifting cultivation, road and infrastructure development and illegal tree cutting by commercial loggers. It was found that soil loss from shifting cultivation was about 43 t/ha/yr whereas soil loss from systematic cultivation was only 13.4 t/ha/yr (Mia, 2000). This should be compared to the usual loss of 2.7–7.2 t/ha/yr in mixed forest-covered land. A completely deforested hill slope loses 120 t/ha/yr of topsoil (Shahid, 1994—as reported in GoB, 2001). The traditional fuelwood gathering and the various dependencies of tribal people on the forest are being jeopardized. Forest degradation and illegal clearing also take place in the Sundarban and Madhuban areas of the country. One estimate puts the annual deforestation rate at 0.3 million hectares, which is three per cent of the remaining forests (Mia, 2000).

Like firewood collection, water collection is also becoming more difficult. The deliberate filling up of ponds, lakes and other natural reservoirs in the last 30 years and over-reliance on groundwater has created an alarming situation in many parts of the country. Overuse of groundwater using shallow tubewells has caused large-scale arsenic contamination in Bangladesh. Lack of organic recycling and deforestation has created a desert-type environment in the northern districts. This has resulted in a demand for more water for irrigation in many areas. Expanding irrigation schemes to sustain multiple high intensity cropping have lowered the groundwater table in most parts of the country.

Years of bad experience with the ill effects of deforestation, government awareness raising campaigns and the spread of education have taught rural people the benefits of planting trees and the importance of vegetation in general. Tree planting has always been a part of the biomass management practiced by the rural people, but these days people plant trees more purposefully and consciously. In rural communities, tree cutting faces much more scrutiny and resistance than it used to, and as a result, there is a social pressure to plant more trees. People are also aware of the commercial benefits of tree planting, and unused or wastelands are increasingly being used for plantations.

In general, Bangladesh does not suffer from serious drought, but the distribution of rainfall throughout the year is far from being even. Whereas during the monsoon season (May to September) there is heavy rainfall and flooding, the winter months (November to March) are dry with practically no rainfall. During the dry winter season, in many northern districts, water shortage and lack of rain affects vegetation. Cattle grazing becomes an additional stress; a critical decision must be made whether to use agricultural residue as fodder or fuel. Deforestation has drastically aggravated the previously prevailing natural condition.

Deforestation has aggravated the problems of water management during flood periods. Cutting down of trees from roadside and coastal areas has made vast areas more vulnerable to flood erosion. The perennial erosion along the banks of many rivers during the monsoon season has been aggravated due to the lack of vegetation. As may be imagined, it becomes extremely difficult to gather biomass fuel during flood periods. Moreover, whatever is collected is wet and cannot be dried easily. In such a situation many flood-affected people cannot cook their food and have to make do with dried and semi-processed foods..

Bangladesh's government has been running a public awareness campaign for over a decade regarding the dangers of deforestation. This has been fairly successful. The Forestry department under the Ministry of Environment and Forests has been encouraging people to plant trees on waste and agricultural lands. The coastal belt afforestation program and the roadside plantation projects have been quite successful. FAO-RWEDP (2002) reports that as much as 87 per cent of all fuelwood comes from sources other than designated forests, but severe scarcity prevails all over the country. Hundreds of thousands of trees are planted every year on the tree planting day through a government-sponsored campaign involving educational institutions, government agencies, NGOs and social organizations. Communities and individuals also take part in the one-day event. Participatory forestry programs have also been successful in some areas. The ongoing government campaign using the phrase "plant three trees for every one cut" is beginning to have some impact on the general public. All these measures have definitely slowed down the deforestation rate to some extent.

Figure 3.1 Bangladeshi children collecting biomass

Source: BUET

Social aspects and implications of energy situation in rural areas

The lower calorific values of the low-grade fuels have caused an increase in both the cooking hours and the quantity of fuel required for cooking. For gatherers, increased biomass requirement implies an increased workload as well as increased gathering time, which as reported by Njie (1995) can be up to three to five hours a day. The collectors, who are predominantly women and children, are also forced to travel longer distances to collect the daily minimum fuel requirement and, as a result, there is a tendency to carry a bigger load in each gathering trip. Fuel gathering takes away a significant portion of the daylight hours, which could otherwise be used for a variety of income generating activities, for skill enhancement training or simply for entertainment/leisure. The hazardous fumes produced by low-grade fuels create health problems for women thus deepening family suffering because women perform 90 per cent of the household work and also a large share of the outside work like crop sorting, parboiling, drying, tending livestock/poultry and looking after the backyard gardens.

Women and children are mostly responsible for collecting tree leaves and twigs in their surrounding areas. Men and women often work together to gather agricultural residue, but cow dung is collected from the grazing fields exclusively by lower income group girls and women, emphasizing the social taboo of handling cow dung.

The emissions from cookstoves vary depending on fuel type, stove design, combustion condition, ventilation, cooking duration, etc. Excessive use of low-grade biomass (52.5 per cent animal waste, 27.5 per cent crop residue in the total biomass cooking fuel mix in Bangladesh; Bala, 1997) in inefficient cooking stoves generates smoke, particulates, carbon monoxide, methane and hundreds of organic compounds including many carcinogens. There have not been many studies relating to the health impacts of the use of biomass in rural Bangladesh. Zhang and Smith (1996) (as reported in Islam, 2002) have estimated the lifetime risk of a typical woman in rural environment from exposure to the cookstove emissions using simple exposure models and published data on disease potencies. Using Zhang and Smith's model results, Islam (2002) has estimated an upper bound for cancer deaths to be 500,000. Acute Respiratory Infections (ARI) in children, lung cancer, chronic obstructive lung diseases like asthma and bronchitis, and birth defects are the more common health hazards due to indoor air pollution from biomass burning. Baqui *et al.* (1997) (as reported in Islam, 2002) attributed 25 per cent of deaths among children aged one to four to ARI. These also include the effects of urban pollution. Using modelling studies from other countries with similar cooking practices, Islam (2002) estimated that 100,000 annual deaths of children under the age of five in Bangladesh could be attributed to ARI. Lung diseases like chronic bronchitis and asthma are quite prevalent among rural women. One study (as reported in Islam, 2002) in Western India found 50 per cent increase in stillborn births in women exposed to cookstove smoke during pregnancy.

The rate of exposure is at its highest during the rainy season when most of the cooking is conducted indoors with poor ventilation. During the rest of the year exposure rates are much lower due to outdoor cooking. The amount of smoke is principally dependent on the dryness of the fuel. Women sometimes spend half an hour just to start a fire in the rainy season and in the process expose themselves to high concentrations of smoke and other pollutants. The comparatively high child mortality and low average life expectancy of rural women in Bangladesh are partially linked to exposure to biomass emission.

Out of 134,000 sq km land area in Bangladesh, approximately 61 per cent is arable land. About 38,440 sq km (1998 estimation) is under irrigation that uses groundwater. Most irrigation pumps are diesel powered. Five per cent of the total generated electricity is currently being used for irrigation (BBS, 2002). The farmers receive electricity at a subsidized rate. Ninety-five per cent of the total land under irrigation uses diesel or electricity to run the pumps (BBS, 2002). Large areas of the country still rely upon human and animal muscle power to irrigate land. The lack of access to commercial energy produces lower crop yields thus perpetuating poverty in these areas.

Every year, a large quantity of vegetable and fruits are wasted because of the lack of preservation. This invariably leads to a situation where farmers do not get a fair price for their produce. Potatoes are the only product that gets preserved in cold storages. Cold storages are purely commercial operations in Bangladesh where the farmers and producers do not play any role. Potato growers merely rent the space. Lack of energy also affects grain processing (parboiling, drying) by the farmers. Farmers lose a considerable amount of grain due to incomplete processing or delay due to shortage of fuel. Traditionally farmers do their own parboiling. In many cases they have to spend a considerable sum of money to use a commercial grain processing facility thus reducing their income.

C. Vulnerability of rural communities to climate change impacts and implications for energy access and adaptation

Bangladesh is a huge delta criss-crossed by a number of major river systems. Except for some hilly areas in the southeastern belt, the whole country is a flood plain barely above the sea level. More than one-third of the country gets submerged under water in a usual monsoon season. With frequent flooding and cyclones, the country is considered to be highly disaster prone, and frequently draws the attention of the international news media. In fact, frequent flooding in the past decade is largely attributed to accumulation of silt on the riverbeds, which greatly reduces the water flow capacity of the major river systems of the country. The large volume of silt has in turn been blamed on widespread deforestation in the northern districts of Bangladesh as well as along the banks of all the rivers. In fact Bangladesh is more affected by deforestation in the Himalayas in India and Nepal. Bangladesh is the flood plains of three mighty rivers—Ganges, Brahmaputra and Meghna originating in the Himalayas. Deforestation in the last three decades has caused these rivers to carry large volumes of silt, which get deposited in the riverbeds inside Bangladesh thus aggravating the flood situation. However, it must be remembered that the creation of the Bangladesh landmass was due to the silt deposits of these major rivers.

Bangladesh has been particularly vulnerable to the extremes of climate in recent times. With a low-lying coastline, high population density, and an economy highly dependent on agriculture, the lives and livelihoods of people are threatened by frequent floods, cyclones, saltwater invasion and droughts. Poor economic conditions restrict the country's ability to deal with any major natural catastrophe. Between 1960 and 1991, Bangladesh was struck by 35 cyclones. The low topography also makes Bangladesh prone to floods and coastal inundation. Between 1974 and 1998, the country experienced seven major floods (World Bank, 2002). In the 1998 major flood, about 68 per cent of the country's geographical area was flooded, affecting more than 30 million people and causing 918 fatalities. Economic losses were estimated to be US$3.3 billion, equivalent to eight per cent of the country's GDP (World Bank, 2002).

Ahmed and Alam (1999) have studied the effects of climate change on Bangladesh. The study provides the scenarios and potential effects of climate change on Bangladesh in 2030 and 2050 as reproduced in Table 3.5.

Table 3.5 Climate change scenarios for Bangladesh in 2030 and 2050

Year	Sea level rise (cm)	Temperature increase (°C)	Precipitation fluctuation compared to 1990 (%)	Changes in evaporation
2030	30	+0.7 in monsoon +1.3 in winter	-3 in winter +11 in monsoon	+0.9 in winter +15.8 in monsoon
2050	50	+1.1 in monsoon +1.8 in winter	-37 in winter +28 in monsoon	0 in winter 16.7 in monsoon

Source: Ahmed and Alam (1999)

The information presented in Table 3.5 has been reported both by World Bank (2000) and the National Communication (GoB, 2002). Ahmed and Alam (1999) concludes—"According to the above scenarios, the magnitude of these changes in climate may appear to be very small. But, if added to the existing climate events (such as floods, droughts and cyclones), these could substantially increase the magnitude of these events and decrease their return period. For example, a 10 per cent increase in precipitation may increase run-off depth by one-fifth and the probability of an extreme wet year by 700 per cent. Thus, within the planning horizon for development activities, it is quite possible that there could be a significant increase in the intensity and frequency of extreme events in Bangladesh."

In another study, Mirza and Dixit (1997) (as reported in the National Communication) analyze the effect of climate change on droughts. The report says that in case of a severe drought, forced by a change of temperature by +2°C and a reduction in precipitation by 10 per cent, run-off in the Ganges, Brahmaputra and Meghna rivers would be reduced by 32, 25 and 17 per cent respectively. This would limit surface irrigation potential in the drought-vulnerable areas and challenge food self-sufficiency programs of the country.

It is clear from the Ahmed and Alam (1999) study that what climate change is likely to do is cause more rainfall in monsoon season thus increasing the severity of flooding, and less rainfall in the dry season thus increasing the severity of droughts. Depending on the scale of these occurrences, disastrous consequences may result. Any measure that lessens or tackles flooding or droughts or their impacts would constitute adaptation. As mentioned earlier, Bangladesh has a severe water management problem—too much water in the monsoon season and too little water in the dry winter season. Trees have been found to address both these issues. During flooding and excessive rainfall, trees have been found to retard soil erosion especially in places prone to such erosion like the sides of elevated roads, the sides of raised grounds where houses have been built and river banks. In general, however, moderate flooding has been found to be beneficial for agricultural soils because a layer of nutrient-rich silt is left behind by the receding floodwaters. In the dry months, the role of trees has been to provide shade thus helping soil to retain moisture.

Soil degradation is intimately connected to the withdrawal of crop residue from agricultural lands. This is happening because the poor and the landless cannot find enough wood-based cooking fuel. The availability of more trees in the rural areas is bound to decrease deforestation and the withdrawal of crop residue from fields thus enhancing soil quality. This provides ample justification for bioenergy projects. The NGO community in Bangladesh, especially those engaged in rural development, is very strong and there is a constant search for good projects. If good projects can be designed for adaptation there will be many NGOs willing to implement them. If the prevention of loss of soil quality can be an added benefit of a CDM project, then many rural NGOs can probably be motivated to undertake such projects. Social forestry, agroforestry and community forestry (roadside plantation being one example) have all taken off thanks to the zeal of the NGOs. A case study on roadside plantation that achieves both mitigation and adaptation to the climate change vulnerabilities is reported in this work.

The IPCC TAR considers food security as the most significant climate change vulnerability in Bangladesh. The TAR reports: "Overall, the rate of undernourishment is very high (37 per cent), as is the prevalence of underweight, stunting and wasting among children. Rates are high throughout the rural areas that are home to 80 per cent of Bangladesh's population. More than 60 per cent of rural households are functionally landless, and there are limited opportunities for income diversification (Mimura and Harasawa, 2000). The level of vulnerability is likely to increase as a result of severe land degradation, soil erosion, lack of appropriate technology and the threat of sea-level rise from global warming. Climate change could result in a decreased supply of water and soil moisture during the dry season, increasing the demand for irrigation while supply drops. Improving irrigation efficiency and agricultural productivity will help make Bangladesh self-sufficient in crop production and reduce undernourishment. Higher yields may enable the country to store food supplies to carry it through low harvest years (Azam, 1996). A switch to growing higher value crops and expansion of free market reforms in agriculture may enable Bangladesh to sell more crops for export. Diversification should help in providing robustness to withstand climate change and variability." The TAR, therefore, puts great emphasis on diversification as a way to cope with climate change.

Rural communities will face several climate change vulnerabilities, of which the following can be considered to be relevant to DRE applications:

- Land degradation from loss of soil organic content, erosion aggravated by deforestation and increased flooding and decreased rainfall in the dry winter months.
- Food security – decreased crop yield resulting from loss of soil organic content, excessive flooding and increased droughts.

The IPCC TAR has highlighted both of the above aspects. It has been discussed earlier how DRE rural electrification can tackle land degradation. TAR discusses some adaptation options to tackle vulnerability to food security with diversification being the pivotal response. Bangladesh is heavily dependent on its fish resources which, according to the TAR, will be adversely affected. A lowered reliance on fish protein will be an effective adaptation response. The development of the poultry industry can effectively compensate the decreased fish protein supply resulting from climate change. The growing poultry industry in Bangladesh is facing tremendous problems with disposal of poultry waste. A case study considered in this report investigates how a waste to energy DRE project can contribute to decreased vulnerability to climate change.

3.3 Decentralized Renewable Energy

A. Current state of DRE activities in Bangladesh

The activities of different organizations, technology employed and political and economic motivation for implementing the particular DRE project are described in the following sections.

DRE implementing organizations

Both government and NGO/private sector organizations are implementing DRE technologies. The important projects of the government agencies and the larger NGOs are given below.

Government agencies

a. PV Programs of the Rural Electrification Board (REB)

   Diffusion of renewable energy technology by REB (Islam, 2000) under a French government grant with some local funding covered 21 villages in isolated river islands of Narshindi (50 km from Dhaka) providing 62 kW solar PV electricity. Solar home systems (SHS) of different categories were provided to 800 consumers. The first phase was completed in 1997. Unfortunately, the selections of these islands were not well thought out and those were connected to the grid in 1998. Since then, villagers are showing more interest in grid connection. Despite the setback, REB plans to electrify 6,000 remotely located consumers using Solar Home Systems (SHS) in its second phase (1999–2004).

b. Sustainable Rural Energy (SRE) projects by LGED

   This is another bilateral development project initiated by the Ministry of Environment and Forest (MoEF) under its Sustainable Environment Management Program (SEMP). Local Government Engineering Department (LGED) is implementing the SRE component of the project funded by UNDP. The main objective of this project is to "explore opportunity for community-based renewable energy options for different applications and its multipurpose use in off grid areas." Specifically, in its early stage, the objectives are to demonstrate and transfer renewable energy technology. The project, started in 1998, has been successful in demonstrating the following:

Solar energy

Completed

- Solar village demonstration program at Baliadangi, Thakurgaon
- Demonstration plant on solar market electrification at Shaikupa, Jhenaidah
- Cluster village electrification by solar PV at Nalitabari, Sherpur
- Solar PV electrification at a community clinic at Terokhada, Khulna
- Demonstration of solar plant in a tourist spot at Goznee, Jhenaighati
- Tribal community electrification by solar PV at Rangamati
- Solar demonstration plant at UP complex Khoksha, Kushtia
- Solar PV demonstration for IT development at Kutubdia, Cox's Bazaar
- Large scale comprehensive solar electrification at a coastal community

Proposed

- Solar thermal energy demonstration at Dhaka
- SPV pumping system – mainstreaming activity with demonstration installation
- SPV egg incubator demonstration for small-scale poultry farming
- Energy Empowerment to rural poor SPV Lantern Program

Bio energy

- Two Biogas plants at two sites in the country (Ongoing, 75 per cent of one plant completed)
- One Bio-gasifier plant at one site of the country (Proposed)
- Bio gasifier demonstration plant at a rice mill (Proposed)
- Bio gasifier program for mainstreaming (Proposed)
- Improved Cookstove Program (Ongoing)
- Biogas electricity generation from poultry waste in an orphanage (Completed)

Wind energy (completed)

- Water pumping unit (windmills) at two different sites
- Wind solar hybrid systems at Kuakata Sea Beach
- 10 kW wind solar hybrid system at St. Martin's Island, Cox's Bazaar
- Twenty wind monitoring stations in different parts of the country

Micro-hydro

- Two small micro-hydro power unit, one at Bamerchara, Chittagong and the other at Bandarban (Proposed)
- Identification of additional locations for micro-hydro (Completed)

Tidal and wave energy

- Setting up of a tidal energy monitoring station at St. Martin's Island, Cox' Bazaar (Proposed)

c. PV Program of the BPDB

Bangladesh Power Development Board (BPDB) engineers, after conducting a feasibility study, are currently implementing a solar photovoltaic project at three Upazillas in the Chittagong Hill Tracts region providing water pumping, vaccine refrigeration, street lighting, etc. The program has been named "Chittagong Hill Tracts Solar Electrification Project."

d. Improved Cookstoves and Biogas Programs of BCSIR

The Institute of Fuel Research and Development (IFRD) of the Bangladesh Council of Scientific and Industrial Research (BCSIR) have constructed 4,664-household level biogas plants between 1995 and 2000. Ninety-nine per cent of these plants are operational and 91 per cent of those provide adequate gas to meet the household fuel demand. In the second phase, 20,000 plants are planned to be constructed by 2004. IFRD has also disseminated its improved cooking stoves along with the biogas plants.

NGO/private sector

a. Renewable Energy Programs of the Grameen Shakti

Grameen Shakti, established in 1996, sells SHSs under various micro-credit and cash schemes. It has 71 local offices throughout Bangladesh and has sold about 14,000 SHSs since 1997. Grameen Shakti has also set up four wind-diesel hybrid systems in Grameen Bank premises at four coastal locations. They have also experimented with a biomass gasifier in Panchagargh (Northwestern Bangladesh), but the project ran into difficulties with the supply of biomass and is now abandoned. Following from the principles of the Grameen Bank, the focus of Grameen-Shakti is to develop micro-enterprises.

b. Renewable Energy Programs of BRAC

Bangladesh Rural Advancement Cooperatives (BRAC), the largest NGO in Bangladesh started its Renewable Energy Program in 1997. By 2000, it had installed 500 PV systems, 1,000 biogas plants, 10 wind turbines and 260 Hot Box Cookers. The PV systems were installed in its branch offices, project offices and some government-owned buildings.

c. Renewable Energy Programs of Rahim Afrooz Bangladesh Ltd.

Rahim Afrooz Bangladesh Ltd. is a private company involved in the business of Solar PV and Solar Thermal. This company's core business is battery manufacturing, and because they see huge prospects for the battery industry in SPVs, they have entered the SPV business even though the business is not profitable. Rahim Afrooz is one of those companies, which has a long-term vision of business and operates with fair degree of social consciousness.

Bilateral and multilateral funded projects

- BUET-Loughborough University Higher Education Link Project: This five-year curricula development and research program funded by DFID, U.K. was started in April 1999. The project has completed a study of the potential of energy in river current of Bangladesh. It has also developed a model water current turbine for harnessing the energy from river current
- SRE project by UNDP discussed above under "Government Agencies"
- Renewable Energy Technologies in Asia (RETs in Asia) Program by the Swedish International Development Agency (SIDA)
- Opportunity For Women in Renewable Energy Technology Utilization in Bangladesh project by ESMAP (35 Women ESCO)
- Solar and Wind Energy Resource Assessment (SWERA) Project by GEF/UNEP
- Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement (PREGA). Ongoing project being executed under the Ministry of Energy (Power Division). Funded by ADB
- Rural Electrification and Renewable Energy Development Project (60,000 SHSs by 2007) by GEF/World Bank
- Promotion of Renewable Energy in Selected Rural Areas of Bangladesh by GTZ

Classification of installed DREs by technology

Solar photovoltaic

Bangladesh Power Development Board installed the first PV cells in Bangladesh for 55 signalling lights in 11 towers of the East-West Power Inter-Connector in 1981. These lights are still working satisfactorily. Later, Bangladesh Inland Water Transport Authority installed 125 solar-powered beacon lights to guide marine vessels in different parts of Bangladesh in 1983. Bangladesh Atomic Energy Commission was one of the first agencies that experimented with PV powered refrigerators, solar light and sound system in a mosque in the coastal island of Swandip in 1988. From the mid-nineties, several agencies have taken up this technology and are trying to popularize it in different parts of Bangladesh.

Wind energy

In Bangladesh, wind technology application hasn't progressed very far, and most installations are little more than experimental. The main hindrance is the lack of good wind-mapping data. A few wind powered water-lifting pumps are operating in different parts of the country. Wind turbine installations for generating electricity are summarized Table 3.6.

Table 3.6 Operating wind turbine installations in Bangladesh

Organization	Type of application	Installed capacity (Watt)	Location
Grameen Shakti	3 Hybrid	4,500	Grameen offices in coastal regions
	Hybrid	7,500	Cyclone Shelter in Coastal area
BRAC	Stand alone	900	Coastal area
	Hybrid	4,320	Coastal area
Bangladesh Army	Stand alone	400	Chittagong Hill Tracts
IFRD	Stand alone	1,100	Teknaf
	Stand alone	600	Meghnaghat
LGED	Wind-PV hybrid	400	Kuakata
Total		19,720	

Source: Islam (2000)

Hydro

Although many surveys and studies have been conducted for small or micro-hydro projects, only one installation in the Banderban district has materialized.

Biogas

BCSIR is the pioneer in Biogas technology development in this country starting its activities in 1973. Since the mid-nineties a number of organizations have installed hundreds of biogas plants in different parts of the country mainly to supply household cooking fuel. LGED has constructed a large plant for generating electricity from poultry waste in an orphanage.

Table 3.7 gives an overall summary of the installed capacities of the different RETs operating in the country.

Table 3.7 RETs in Bangladesh

Technology	Installed capacity (approximate)
Solar photovoltaic	1,100 kWp, 20,000 SHS
Wind turbine	20 kW
Wind pump	8–10
Biogas plants	20,000 (Operating 10,000)

Source: LGED Web site

Figure 3.2 Biogas electricity generator at Faridpur Muslim Mission

Source: BUET

Political and economic motivation

SRE of LGED

Sustainable Environment Management Program (SEMP) is a UNDP supported program, which is a follow-up to the National Environment Management Action Plan (NEMAP). The project is implemented under the supervision of Ministry of Environment and Forest (MoEF). As a multi-dimensional follow-up action of NEMAP, SEMP aims at sustainable environment management, sustainable human development and attaining breakthrough in the poverty situation by helping the poor particularly the women. It is aimed to build community capacities for sustainable management of environmental resources. SRE is a component of SEMP and is intended for developing community based natural resource management. Local Government Engineering Department (LGED) is the largest government agency that is equipped to give technical support for all local government development activities. It has a major mandate for sustainable rural development and has offices at the Thana level (smallest administrative unit). LGED has a large number of engineers and technicians who can provide adequate support for DRE projects. These factors led to the choice of LGED as the implementing agency. The main purpose of the SRE project is to demonstrate and transfer the technologies related to the use of renewable energy in off-grid areas of Bangladesh.

Grameen Shakti program

Grameen Shakti is a subsidiary of Grameen Bank, the organization that pioneered the micro-credit concept in this country. Grameen Bank is a large non-government organization whose main objectives are poverty alleviation and the empowerment of women. As a part of that goal, Grameen Shakti was established in 1996 to develop and popularize renewable energy technology. At present it has offices in 52 districts. It has received grants and loans under different bilateral and multilateral partnerships comprising GEF, IFC, USAID and SIDA. It sells, installs and maintains photovoltaic systems for mainly single households all over the country (off grid). They have three credit systems for the customers with different repayment schemes. Discounts are allowed for cash purchase.

BRAC renewable energy projects

BRAC was established in 1972 as a relief organization. Later, it changed its objectives to eradicate poverty and empower the poor. It is now one of the largest NGOs in the world and has multidisciplinary operations including agriculture, poultry-livestock, sericulture, fisheries, handicraft, printing, publishing, dairy, banking, micro-credit, formal and informal education, rural health, legal aid for the poor, etc. Most of its initial programs were aid-dependent, but in recent years it has become more self-reliant. Since 1997, when it started the solar energy program, it has spent millions of taka on renewable energy. Most of these projects have been implemented in its own network of a large number of offices and other establishments.

BCSIR

This is the oldest government research and development organization in Bangladesh and is involved in a variety of areas including renewable energy. Since 1973, it has been involved in pilot scale dissemination of improved cookstoves and biogas plants. From the very beginning all its funding has come through the annual development budget of the Bangladesh Government. It plays a major role in raising public awareness about renewable energy technology through seminar, symposium, training, workshops, etc. BCSIR is the reflection of the government's commitment to deliver a better standard of life to the poor people of this country through alternate and improved energy sources. Lack of funds and policy indecision have been the principal barriers to achieving its goal.

B. Case studies

CASE STUDY I: Social Forestry (Roadside Plantation) Project of Caritas

General context

Roadside plantation, which started in the early nineties, is an important component of Social Forestry Project (SFP) of Caritas Bangladesh, a national NGO. The objectives of the project are to utilize available resources, establish the rights and access of the poor to those resources, share the income generated out of the project with the poor and improve the rural ecology through forestation. The plantation consists of mainly firewood and timber trees. The roadside trees are pruned twice a year and the branches are used for firewood. In addition, every morning village women sweep the roads to collect leaves and twigs that are used as cooking fuel. The project has increased the availability of biomass fuel in the project area for the rural poor. Therefore, such projects have the potential of becoming successful decentralized rural energy (DRE) projects.

Bangladesh has been facing shortage of wood since the early eighties. The annual deforestation rate stands at over one per cent of the remaining stocks. Projects like the one mentioned above increase the availability of tree products in the rural community. The nature of these plantations is such that during the life of a plantation it contributes biomass (as explained later) which is used for cooking purposes. At the end of the life of the project, the trees are harvested thus contributing a stock of wood that might have contributed to deforestation. However, there is uncertainly about re-planting after harvesting. In addition, road expansion will interfere with future re-plantation programs. These uncertainties imply that this project cannot be an afforestation/reforestation CDM project because permanent increase in carbon stock cannot be demonstrated. The project however can be a good avoided-deforestation CDM project because it produces sustainable biomass. The emission reduction is equivalent to deforestation avoided from this bioenergy supply. The use of a managed source as opposed to an unmanaged one is the basis for claiming avoided deforestation. However, because a variety of energy sources are employed for rural cooking, an assumption on how much deforestation can be avoided needs to be made

The project was started in 1992 and has passed a number of phases with the support of the World Food Program (WFP). Under the project, roadside plantations have been carried out primarily in the districts of Dinajpur and Rajshahi. The are some small-scale roadside plantations in the districts of Barisal, Dhaka and Mymensingh. Out of the total 210 kilometers of roadside plantation of Caritas Bangladesh, 107 and 48 kilometres are in Rajshahi and Dinajpur districts respectively. Dinajpur can be considered to be a high altitude flood plain but Rajshahi district contains Barind tract, which is low in natural fertility with low moisture holding capacity.

Caritas Bangladesh has provided administrative and technical support to the project in which the beneficiary groups comprise of the poor people. The project has resulted in a number of benefits for the beneficiary groups and has made positive impacts on the local environment. This case study (i) describes the technical characteristics and management structure of the project, (ii) evaluates the socio-cultural and socio-economic impacts of the project, (iii) describes the climate change relationship, and finally, (iv) makes an overall assessment of the project.

Technical characteristics

The project is distributed in a number of districts, but the major portion of the project is located in the districts of Dinajpur and Rajshahi. These districts are located in the northwestern part of the country. The region is relatively disadvantaged in terms of energy resource endowment and energy availability, and hence is one of the economically less developed regions of the country. The Jamuna River divides the country into two parts—the eastern zone and the western zone. The eastern zone of the country is well endowed with natural gas. With most of the power plants located in the eastern zone, the energy scarcity in the western zone was very pronounced until the year 2000, when the Jamuna Multipurpose Bridge was built establishing road, railway and natural gas links between the eastern and the western zones. Even after construction of the Jamuna Multipurpose Bridge, extension of the natural gas network in the western zone is being carried out at a very slow pace because of financial and other limitations. The only commercial energy resource in the western zone is coal. The Boropukuria coal mine being developed at Dinajpur is expected to start commercial production in 2004. The western zone has been suffering from electricity and fuel shortage for a long time, and the rural poor have been the worst victims. People in the region rely heavily upon biomass fuels, and this is causing environmental degradation like deforestation, soil erosion, loss of soil fertility, etc. Social forestry has been a timely and important project for the western zone of the country.

Management structure

The project involves a total of 5,095 beneficiaries, of which 55 per cent are female. The beneficiaries have been selected by Caritas on the basis of a baseline survey and have been divided into 251 Primary Groups (PG). The criteria for becoming a Primary Group member are:

- age should be between 18 and 52 years;
- monthly family income should be less than Taka 2,500;
- land ownership of the family should be less than 0.5 acre (1 acre = 0.405 hectare); and
- highest education level completed should be less than Grade 12.

A Primary Group may have 20 to 30 members but the members are either all female or all male. Under the project Caritas organizes the Primary Groups, provides saplings (covers 60 per cent cost of the saplings, rest provided by the PG members), and provides technical and motivational support. The

World Food Program (WFP) provides support for planting and maintaining saplings for three years. Usually a tract of one kilometer is assigned to a Primary Group. The group plants about 1,000 saplings on two sides of the one-kilometer road. The members of a Primary Group select a caretaker for each kilometre of roadside plantation, and the caretaker is given 4.5 kg of wheat per day from WFP for taking care of the saplings. It has been found that this and other (described later) immediate benefits have had a very positive impact on the project beneficiaries. This aspect of short-term benefits accompanying long-term ones is therefore an important part of project design for ensuring success.

As the local government owns the roads, tripartite contracts are made among the local government (first party), Caritas (second party) and primary groups (third party). The contract stipulates that the final harvest will be shared 20 per cent; five per cent and 75 per cent among the first, second and the third parties, respectively. There is a Project Implementation Committee in each Upozila (smallest government administrative unit) in the project area. The members of the Project Implementation Committee are:

- one representative from each Primary Group;
- caretakers of each Primary Group;
- female member of the Union Parisod (One Upozila consists of a number of Union Parisod, each Union Parisod has one female member); and
- one Caritas official from the local office.

Currently, none of the project sites have had their final harvest. Besides the final harvest pruning is done twice a year. Pruning constitutes cutting off small branches and twigs from the trees. This activity enhances tree growth. Pruning results in about 200 to 300 tonnes of biomass fuels annually depending on the species of the trees. The members of the respective Primary Group share the benefits. Primary Group members are also involved in other integrated projects of Caritas such as: Micro Credit Program, Sericulture Program, Development Extension Education Service (DEEDS), Integrated Community Development Project (ICDP), Integrated Women Development Project (IWDP), Technical Training Program, etc. Primary Group members are given preference in providing support and services to these projects and programs.

Socio-ecological and socio-economic impacts

Roadside plantation under the Social Forestry Project of Caritas is helping the relatively poor sections of the rural people. As stated earlier, the members of a Primary Group have at most grade 12 level education with monthly family income less than Taka 2,500 (US$42). Although job creation of the project is not very significant, one person as caretaker is employed per kilometer of roadside plantation. In addition, for every kilometer of roadside plantation 20 man-days of work for a day-labourer for planting saplings is created. Depending on the types of trees, maturity is attained in 10 to 20 years. Some of the trees have reached pre-maturity stage but none of them has been harvested yet. It is difficult to say whether the villagers will replant trees or not. It is expected that the ensuing financial benefit will encourage them to do so. About 1,000 trees were planted per kilometre of road length and roughly 900 have survived. This constitutes a fairly dense plantation, and since pre-maturity for every kilometre of roadside plantation (taking both sides) 200 to 300 tonnes of biomass products are being generated. This biomass is collected during pruning, which is done twice a year. The harvested biomass is either sold in the local market as fuel and the benefits shared by the Primary Group members or, divided among the members who use those as fuel. Additionally, the rural people from the surrounding area collect leaves of the trees during the fall season for use as a cooking fuel. Therefore, the roadside plantation projects are supplementing the income of the rural people and alleviating the fuel crisis in the surrounding areas.

The project has some secondary benefits as well. The project helps the rural poor people to organize themselves, to analyze their socio-economic conditions, and motivates them to do something collectively to improve their condition. The project helps to establish the rights of the rural poor people on some common resources and helps them enjoy some of the benefits. Additionally the project motivates and organizes the rural people to participate in micro credit program, other development and income generating activities and in educational programs of Caritas.

Climate change relationship

As explained earlier this is not a sequestration project but a bioenergy project based on avoided deforestation. The GHG reduction results from the fact that fuelwood and fodder requirements are being met from a managed source rather than an unmanaged one. The project's GHG reduction can be increased if deforestation is reduced even further by coupling an improved cookstove program so that the harvested biomass was used at higher efficiency. Roadside plantations are reversing the deforestation process being experienced in the western zone of the country. It is worth pointing out that deforestation, especially in the western zone, is a major concern for the country, and the government is sympathetic and supportive of the social forestry programs of the NGOs.

It is a well-known fact that trees help to retain moisture in the soil thereby aiding agricultural activities. Trees also enhance rainfall and alleviate the severity of droughts. Roadside plantation is helping to reduce soil erosion thereby alleviating the severity of flooding in the project areas.

The Roadside Plantation project is also contributing positively towards reducing the vulnerability of the rural people to severe climatic conditions. The project is enhancing the fuel supply of the rural people and supplementing their income. It is also making positive contributions towards arresting environmental degradation and reducing soil erosion. The project also creates a stock of energy (biomass), which can be used by the rural poor people in case of any natural calamity such as severe flooding, droughts, etc. The project is therefore improving the adaptation capacity of the rural poor people in several ways.

Overall assessment

Increased energy supply, poverty alleviation and vulnerability reduction of the rural poor people were the main driving forces for the Social Forestry Project of Caritas. Roadside plantation establishes the rights of the rural poor on some energy resources and helps them to share its benefits.

The Roadside Plantation has contributed to the scenic beauty of the place, and people use the road for taking a stroll in the early morning and evening. Farmers and labourers use the shade of the trees. In general, the trees have contributed towards building a psychologically uplifting environment. The villagers have truly appreciated the project.

Despite all the positive aspects, these projects have encountered some difficulties. Getting the support and cooperation of the local government bodies have been a challenge in many project areas, even though social forestry is a stated policy of the government. Since the very poor and marginalized people are the main beneficiaries of the project, there remains the fear that they may get cheated by the local influential people. It is important that the Primary Group members get appropriate support and assistance of the local government for ensuring the success of the Social Forestry Project.

The project is dependent on the support of the World Food Program (WFP), which provides wheat for the caretaker and day labourers. WFP distributes wheat through the local government bodies, a process that frequently results in pilferage. Consequently, WFP has withdrawn its support and the whole project has been stalled. Administering the support through Caritas and providing cash benefit instead of wheat can overcome this problem. The project also causes some friction between the Primary group members and the owners of the roadside houses. Incorporating the roadside people in the beneficiary group can be a tactical way to handle this problem.

Although there are some limitations, Social Forestry Projects can be very successful Decentralized Renewable Energy (DRE) projects. There is no expensive or complicated technology involved, unlike in the cases of PV and biomass gasification. The rural people can be easily motivated to participate in such projects. Investment and support needed for such projects are also not very significant. Apart from increasing biomass energy supply, the project brings in a number of socio-economic and ecological benefits to the rural people making them less vulnerable to the natural calamities. The project can be replicated in the neighbouring communities provided some administrative changes are made in its present approach.

CASE STUDY II: Biogas electricity generation from poultry waste

General context

Identifying biomass as the main source of energy for rural areas, the government put emphasis on its proper and efficient use right after the independence of Bangladesh in 1971. Bangladesh Council for Scientific and Industrial Research (BCSIR) started its biomass research in 1973. As a continuation of the effort, biogas is being promoted all over the country by different government and non-government agencies along with BCSIR. Local Government Engineering Department (LGED) was created to mainly provide technical support to the local government institutions. This organization plays an important role in disseminating appropriate technologies all over the country through its setups at the Thana level. LGED constructed its first Biogas plant in 1986 in Kurigram. So far they have constructed 300 biogas plants in different districts of Bangladesh, of which 106 are based on night soil, 15 on garbage, three on poultry droppings, two on water hyacinth and the remainder on cow dung.

With increasing population, the demand for protein including eggs is rapidly increasing in Bangladesh. The emerging poultry industry is growing all over the country to meet that demand. Poultry industries require heat and light for incubators and rearing of birds. This heat is generated from either electricity or natural gas but in some remote areas biomass is used to provide the heat.

As a result of the success of its biogas plant from poultry droppings, LGED has developed an electricity generator that can use the biogas generated from poultry droppings. Faridpur Muslim Mission School, an orphanage for 500 students, is located 60 miles southwest of Dhaka city in Faridpur district. LGED has installed a four kW electricity generation unit that runs on biogas generated from poultry droppings. The project was completed in 2002. This school is located at the outskirts of Faridpur district town and is within the national electricity grid. Faridpur is an agricultural district consisting of plain flooding zone. The natural gas pipeline network has not reached Faridpur and most people use biomass for cooking, but the use of LPG is becoming more popular among the affluent. LGED has set up this DRE project mainly for the purpose of demonstration.

The untreated disposal of poultry waste is an environmental hazard and that can exacerbate soil degradation. Converting to biogas creates a large GHG benefit (from grid displacement and methane emission reduction) and produces high quality fertilizer, which is in short supply in Bangladesh.

The IPCC TAR reveals that in most of tropical Asia, climate change will adversely affect fish resources. The switch to poultry from fish is an adaptation strategy because the fish population is declining due to ecological stresses that can be expected to worsen under climate change. Therefore the need for poultry-based protein will increase as a result of climate change. The poultry industry in Bangladesh has no system to dispose off the poultry waste and in most large farms this is becoming a major concern. The present disposal method is either open dumping in a pit or dumping in ponds as fish feed. This waste to energy DRE project therefore increases rural livelihood opportunities and increases adaptive capacity by allowing poultry farms to become environmentally sound and financially better off.

Technical characteristics

When litter like poultry droppings and cow dung or any agricultural residue is fermented under anaerobic condition, a clean gas commonly known as biogas is produced. It contains 50 to 70 per cent methane, the balance being mainly carbon dioxide, hydrogen sulphide and moisture. By burning this gas, electricity can be generated and the slurry can be used as a good organic fertilizer.

A poultry shed of about one thousand square feet was constructed under the project. After meeting the demand for eggs and chicken for the students, all surplus products are sold to the market. This poultry farm has become an income-generating unit for the school. At present, there are 5,000 birds on the farm. The Mission has plans to increase that number to 20,000.

The collected poultry waste is charged into the inlet chamber. The droppings enter the fermentation chamber by gravity. Gas is taken out from the top of the dome shaped gas chamber for processing. Before the gas enters the combustion chamber of the engine, hydrogen sulphide and moisture are removed from the stream. The slurry is collected via two collection pits after it passes the hydraulic chamber. The organic fertilizer is used in the large vegetable garden within the school premises. Additional fertilizer is sold to the local market. The four kW gas generator produces electricity for three to four hours a day which is consumed in the poultry farm. The generation can be raised to 10 kW when the number of birds is increased to 20,000. The capacity of the biogas plant is 200 cubic feet.

Management structure

This pilot demonstration plant has been set up under the Sustainable Rural Energy (SRE) project, which is a component of the Sustainable Environment Management Program (SEMP) being executed by the Ministry of Environment and Forest and funded by UNDP. The total cost of the project was about Taka 0.7 million. The cost breakdown for the project is shown in Table 3.8. It is worth pointing out that Taka 0.7 million is the total cost of building the entire poultry project including the DRE component. The cost of only the DRE portion would probably not exceed Taka 120,000. The SRE funded 70 per cent of the project and the school authority financed the rest. The management committee of the Faridpur Muslim Mission is responsible for managing the poultry farm, the biogas plant and the operation and maintenance of the power unit.

Table 3.8 Cost breakdown (in Taka)

Capital investment	
SEMP contribution	495,000
Muslim Mission contribution	198,000
Yearly operation cost	
Labour	30,000
Technical	36,000
Maintenance and repair	10,000
Total yearly cost	78,000
Annual income	
Savings on electricity	20,000
Sale of fertilizer	85,000

Socio-ecological and socio-economic impact

Faridpur Muslim Mission is an institution for the rehabilitation of orphans and destitute children. The Mission established an orphanage (school) in 1984 that provides food, shelter and education to 400 orphans. Along with the resident students, the orphanage houses about 50 staff members. Other than formal education, the students receive vocational training in subjects such as pisciculture, cattle farming, automobiles, lathe machines, welding, carpentry, electric works, electronics, garments manufacturing, computers, etc. The technical training centre is open to non-resident participants. The school comprises a modern building and plenty of open space to accommodate the various activities of the orphanage.

The selection of such a project within the national grid coverage was mainly due to the unique social and organizational structure of the school. The fact that LGED was already running a human excrement-based biogas plant in the school also played a part in the selection process. The school had four cook-stoves that used fuelwood, cow dung, jute stalks and other available biomass. One of these stoves was replaced by the earlier biogas project. The school has benefited immensely from the establishment of the poultry farm. The farm now provides chicken and eggs to the students and staff members. A new vocational training subject in poultry farming has been added to the list of subjects taught at the technical training centre and hands-on training is provided to the students. This poultry project has turned into a major income-generating activity for the Mission. From a financial point of view, the integrated approach has made this project a safe investment for LGED/UNDP. The project has successfully shown that bioenergy technology can deal with the waste disposal problems of the emerging poultry industry.

The commercial poultry industry is growing rapidly in Bangladesh. Both eggs and chicken consumption in Bangladesh have been rising at more than 10 per cent annually for the past several years. Estimates shows that poultry population is increasing at the rate of 6.5 per cent per year in the country. There are over 116.5 million chicken and 13.47 million ducks in Bangladesh. The declining fish population in the country is perhaps putting pressure on poultry and eggs to meet the protein demand. According to a 2001 census completed by the Department of Livestock Services (DLS) and the Poultry Sector Development Project (PSDP), there are approximately 22,570 commercial poultry farms housing 8,410,000 layers and 5,784,500 broilers in Bangladesh. These poultry farms are producing approximately 4,474 tonnes of excreta per day (i.e., 1.63 million tonnes per year). An increasing number of entrepreneurs in Bangladesh, from villagers raising only 100 birds at a time to large hatcheries producing 100,000 or more chicks per week, are getting into the business.

Egg production requires controlled temperature and humidity. Similar environment is also required for the chicks. Most of the large hatcheries use electrically operated incubators and are located in the grid area. The production loss due to power supply interruption is more than 12 per cent per year. In off-grid areas, slow burning biomass (straw, jute stalks, etc.) or gas in crude incubators is used to maintain the required temperature. All poultry farms in the country can benefit from the DRE project demonstrated in the Faridpur Muslim Mission. The surplus electricity can be used in the adjacent houses or to develop small/cottage industries within the Mission premises.

The pollution from poultry waste is an environment hazard. At present all manner of ad-hoc disposal methods are employed. Use of poultry waste as fish feed has had some success. The common practice is of course open dumping in some shallow ground. In a recent survey, an NGO (Waste Concern, 2003) found that disposal of poultry droppings is becoming a critical environmental issue in villages. Not only does it degrade land because of its high nitrogen content and propensity to encourage pathogen growth, but also it creates unhygienic condition in the dumpsite. It must be appreciated that villages do not have managed dumpsites. The poultry biogas plant being an environment friendly technology with very favourable financial returns (from power saving and fertilizer sales alone), can be replicated throughout the country. This will encourage the growth of the thriving poultry industry in off grid areas. Dhaka is one of the fastest-growing cities in the world. The migration of people from the villages to the cities is exerting tremendous pressure on the cities' utility infrastructure. Job creation in the rural areas, where about 80 per cent of the people of this country live, will lessen the migration tendency and relieve the pressure on the major cities. In this project because electricity is produced on-site using the gas generated from the biogas plant, the following additional activities must be performed: collecting droppings and replenishing the biogas plant; maintaining generator and biogas plants; operation of generator and electricity distribution systems; and collecting the bio-fertilizer for subsequent use. These activities create one full-time job at the school.

During the last three decades the use of chemical fertilizer has increased agricultural production. The increased use of chemical fertilizer along with the indiscriminate use of pesticides have reduced the fertility of agricultural lands. Over-cropping and removal of crop residue and animal waste from agricultural lands have added to that problem. Where a soil should have at least three per cent organic compound for good production, in many areas of Bangladesh this has come down to less than one per cent. This is causing decreasing crop yield and poses a major threat to the agricultural sector. The use of organic fertilizer is a possible solution to this problem because it can revitalize agricultural lands that have depleted organic matter.

Climate change relationship

This project is both an avoided landfill emission and waste to energy project. It is assumed that by controlled digestion, the methane emission that would have occurred if the droppings went to a landfill site, are prevented. The methane produced is used in a gas engine to generate electricity that displaces natural gas in a power plant. The CO_2 equivalent emission of the avoided methane emission is several times that of the displaced CO_2 emission from the power plant, and therefore, the emission calculation for the latter is neglected.

The avoided methane emission calculation for the project is given below:

CO_2 eq. methane emission factor = 0.24 kg CO_2 eq./kg of droppings

Waste per bird = 115 kg per year

CO_2 emission per year for 5000 birds =

5,000 x 115 kg/yr x 0.24 kg/kg x 1 tonne/1000 kg = 138 tonne CO_2 eq.

Since not all poultry litter goes to a dump and in many places aerobic decomposition takes place, an assumption still needs to be made as to what percentage of the total emissions are avoided. Moreover, since no fixed landfill site is used, uncertainty exists about how long the anaerobic decomposition occurs. An estimate of the total emission reduction can be made by assuming that 50 per cent of the total anaerobic potential emission is avoided for a period of five years. Therefore,

CH_4 emissions avoided in five years by one unit = 138 x 0.50 x 5 = 345 tonnes CO_2 eq.

There are more than 2,000 farms in the country that have at least 5,000 birds. If this project can be replicated in even 400 farms, the CO_2 savings would be 138,000 tonnes, which is a good size small-scale CDM project.

This project therefore reduces a significant amount of methane emission. If the biogas is used for generation of electricity, dependency on fossil fuel will decrease. In addition to these benefits, the use of the biogas plant slurry, which is an excellent organic fertilizer, will help reduce the soil degradation problem in many areas of Bangladesh. As discussed earlier, the soil degradation problem will be aggravated by climate change and exacerbate food security vulnerabilities.

Overall assessment

At present, 55 per cent of the total energy in Bangladesh is supplied by biomass. Conventional energy resources of the country are limited to natural gas. Due to policy indecision, proper exploitation of that resource is being delayed. The pressure to develop alternate sources of energy is mounting every day. In the early stages of development of DRE technologies in the country, proving the effectiveness of the technologies and convincing potential clients of their benefits was by itself a challenge. Generating electricity from poultry droppings was a novel idea that was identified by LGED because of its large potential in the thriving poultry industry in Bangladesh. It is hoped that seeing the success, others would be interested to adopt the technology. The project has been particularly successful because of the integrated nature of the application at Faridpur Muslim Mission.

This DRE project can easily be replicated in all medium-size (5,000+ birds) poultry farms in the country. The project has already been proven to be economically viable and technically feasible. Large initial investment, lack of proper motivation and training, commercially unproven technology and general skepticism regarding renewable energy are the main barriers to implementing DRE projects. Lack of government patronage, delays in renewable energy policy adoption and the absence of a central government agency to promote and supervise DRE projects are the main policy obstacles that are hampering the progress of all DRE initiatives. For DRE technologies to become successful CDM projects, these barriers must be removed. However, this is a larger institutional design problem than merely establishing the DNA for the CDM and emphasizes the important role that the North still must play in research and development, technology transfer and capacity building.

4. Country Study: Brazil

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http://www.ivig.coppe.ufrj.br

4.1 Introduction

Climate change and decentralized renewable energy are important issues in today's discussions about development in Brazil. Brazil's population is about 170 million. The country has an installed electricity capacity of 73.4 GigaWatts (GW), 85 per cent of which is hydropower (as of January 1, 2001). Of the 321.2 terawatt-hours (TWh) generated in Brazil in 2001, 83 per cent was from hydropower (down from 91 per cent in 1999). Brazil ranks consistently as one the world's top hydropower producers. Brazil's remaining electricity generation capacity comes from coal, nuclear and increasingly from natural gas. Imports from Argentina also augment Brazil's domestic electricity supply.

Hydropower is still responsible for the greatest part of electricity energy supply (about 80 per cent), but thermal generation is increasing.

Electricity generation by the public and the private sectors is outlined in in Table 4.1.

Table 4.1 Brazilian private and public electricity generation from 1986 to 2001

	1986		1990		1995		2000		2001	
	10^3 MWh	%	10^3 MWh	%	10^3 MWh	%	10^3 MWh	%	10^3 MWh	%
Total production	202,128	100%	222,820	100%	275,601	100%	347,733	100%	322,361	100%
Public power plants	191,473	95%	210,913	95%	260,678	95%	322,464	93%	296,237	92%
Auto-generation	10,655	5%	11,907	5%	14,923	5%	25,269	7%	26,124	8%

Source: Brazilian Energy Balance, 2002 (table 2.25)

Table 4.1 highlights the increase of electricity supply in Brazil from 1986 (202,128 TWh) to 2000 (347,733 TWh) and a small reduction in the participation of the public sector in power generation during the same period—from 1986 (95 per cent) to 2000 (93 per cent).

In 2001, Brazil faced a critical electricity shortage, due to drought-induced hydropower production shortfalls and under-investment in new generating capacity. Several years of below-average precipitation had reduced reservoir storage levels by 70 per cent. As a result, electricity rationing reduced total consumption in 2001 to 322 TWh from 348 TWh in 2000 (BEN, 2002). Throughout the 1990s, demands had consistently outstripped new generation capacity as a consequence of economic growth and a rising standard of living. In 2000, consumption had increased by 58 per cent over 1990, while installed generation capacity grew by only 32 per cent during the same period. The supply deficits and rationing of 2001 realized the situation that analysts had long feared.

Brazil is the largest energy consumer in South America (consuming 8.78 quadrillion Btu of commercial energy in 2001), and the third largest in the Western Hemisphere, behind the United States and Canada. Brazil's per capita consumption is only average, however, for Latin America. Per capita electricity consumption, for example, is about 500 kWh per year, compared to an OECD average of about 8,000 kWh (WEA, 2000).

The use of biomass for energy is mainly applied in the industrial sector (50 per cent), followed by residential use (17.5 per cent), energetic sector[1] (15 per cent), transport (12 per cent) and agriculture (4.3 per cent) (BEN, 2002).

This country study reviews the policy context for DRE and features a bioenergy-based village power project in Amazon—the most energy impoverished region of Brazil—highlighting the potential for DREs to contribute to both adaptation and mitigation objectives.

4.2 Energy-Poverty-Environment (Rural) Context

A. Rural energy situation

Although the overall rural electrification rate in Brazil (about 70 per cent) is far higher than the Latin American average (51.5 per cent), electricity accessibility consumption in Brazil is noteworthy for some prominent regional inequities (Table 4.2). The northeast has almost 30 per cent of the population and has the lowest domestic consumption per capita, while the southeast, which is the most industrialized part of Brazil, has the highest per capita consumption and comprises 42 per cent of the population.

Table 4.2 Regional analysis of residential consumption – 1999

Region	Population (million)	Electric residential consumption (GWh)	kWh/cap
North	12.4	3,604	290
Northeast	46.8	11,948	255
Southeast	70.8	47,283	668
South	24.7	12,667	513
Centre – west	11.4	5,828	511
Total Brazil	166.1	81,330	490

Source: National Energy Balance, Synopsis 2000, and Almanaque Abril-Brasil, 2001

According to IBGE (Brazilian Institute on Geographic and Statistics), Brazil had a population of 168.45 million living in permanent private households in 2000. From this total, 157.46 million have access to electricity and around 11 million do not.

While almost all urban households in Brazil have electricity, 1.5 million rural homes do not (PNAD, 2001). Another important source of information is the 1996 Agriculture Census, which focuses only on agricultural businesses, and it estimates that 2,113,276 households in rural areas have no access to electrical service (IBGE, 2000). In 2000, the rate of electrification in the rural households was 71 per cent.

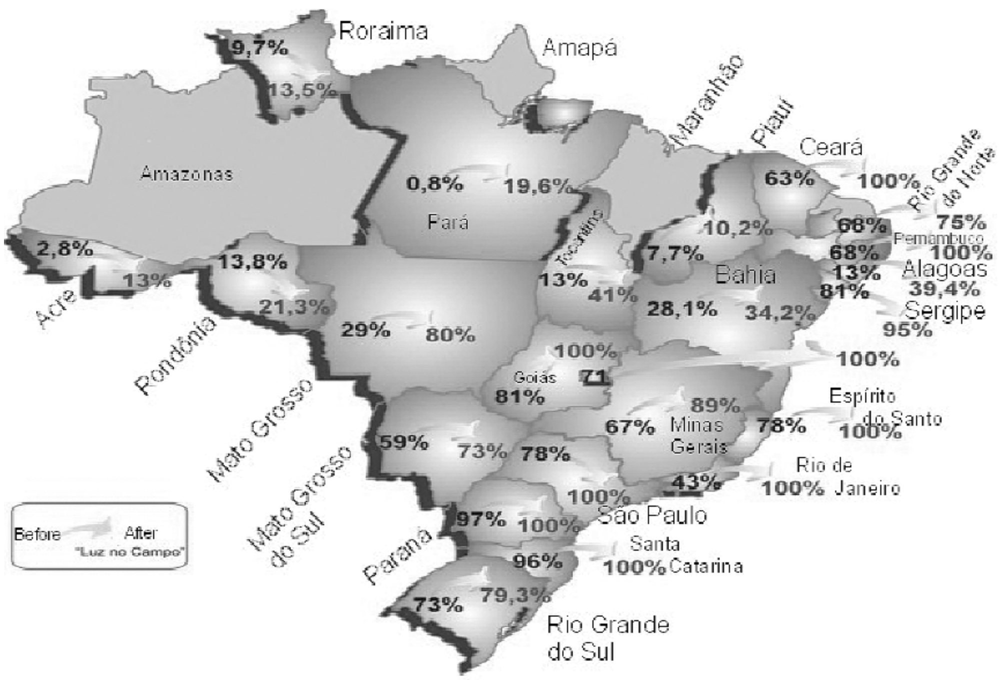
Table 4.3 Permanent private residences and permanent population in urban and rural areas (million)

	Permanent private households			Permanent population		
	Total	Urban	Rural	Total	Urban	Rural
Total	44.78	37.37	7.41	168.45	136.98	31.47
With electric lighting	42.33	37.04	5.29	157.46	135.74	21.72
Without electric lighting	2.45	0.33	2.12	1.099	1.24	9.75
Rate of electrification (%)	94.50	99.00	71.00	93.00	99.00	69.00

Source: Demographic Census, 2000, IBGE

Figure 4.1 depicts the state-wide status of rural electrification in Brazil (before and after a government-sanctioned rural electrification program). Rural electrification rates are lowest in the north (and also suffers a paucity of reliable data), and highest in the south (93 per cent with electricity) and in the southeast (89 per cent), which are the most developed areas in Brazil. In general, about 30 per cent of rural households have no electrical energy access. Eletrobrás (Brazilian Electric Company) has consolidated data from PNAD 1998 and the Agriculture Census to determine the current status of rural electrification for each state. It identifies huge disparities in the rural electrification rates among states, which vary from 96 per cent in Santa Catarina (southern region) to 0.8 per cent in Pará (northern region). The low rate of electrification in the north (still below 50 per cent in most northern states) creates an important opportunity for decentralized energy generation.

Figure 4.1 Decentralized electrification program "Luz no Campo," electrified rural households before and after its implementation



Source: Eletrobrás, 2003.

B. Poverty and the environmental implications of the rural energy situation

Although energy consumption is not an absolute indicator of quality of life, it can indicate some important differences among regions in terms of wealth patterns. Significant differences can be observed between southeast (668 kWh/cap in 1999) and northeast (255 kWh/cap in 1999) regions of Brazil. The southeast region has a better quality of life, higher GDP and higher income per capita than the northeast region.

A study based on the 1998 National Household Sample Survey (PNAD 98) in Oliveira (2001) shows that 40 per cent of families with a monthly income less than the equivalent of one full-time minimum wage have no electricity service, compared to only 1.3 per cent for high income households. Although some rural households without access to grid electricity use small diesel generators, a typical characteristic of rural energy poverty is high biomass energy dependency, including the use of firewood for cooking. Subsistence biomass collection, most common in northern Brazil, is a household activity learned early on by children, though often shared by all household members with or without remuneration. Although detailed data on household biomass use in rural Brazil are scant—it is common in northern Brazil, and the international literature emphasizes the negative health effects from exposure to high concentrations of particulate material from low-efficiency biomass combustion.

Unmanaged fuelwood extraction without reforestation can exacerbate deforestation, although in Brazil, the biggest driver of deforestation is agriculture. In Brazil the deforestation rate from charcoal production and firewood extraction peaked in the 1980s. Since then, the rate is decreasing and the great majority of firewood and charcoal comes from planted forest. Reforestation to create bioenergy plantations is a well-established development objective (Brazilian Charcoal Association, 2000).

Rural bioenergy management can contribute to adaptive capacity and the increased resilience of local communities, but will depend on the appropriateness of the species and land-use choices for the communities in question. Tree planting or forest management are not typical characteristics of Brazilian rural communities, however financial and political incentives could change this. A more direct benefit of energy supply is the application of irrigation and agricultural post-harvest technologies that increase productivity and food security.

C. Vulnerability of rural communities to climate change impacts

According to the IPCC (IPCC, 2001), vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity, and adaptive capacity is in turn a function of social, economic and environmental attributes (Smit and Pilifosova, 2003). We will review the vulnerability of the agriculture and water resources sectors in Brazil, both of which are very relevant to DRE policy analysis.

Agriculture is a fundamental source of livelihood for over a million families in Brazil and the potential climate change impacts on agriculture are numerous and complex, and thus of serious concern for Brazil. Unfortunately, very few country-specific studies about vulnerability exist in Latin America. Table 4.4 provides an overview of climate change vulnerabilities in Latin America.

Table 4.4 Key climate change vulnerabilities in Latin America

Latin America	Likely regional impacts of climate change	Vulnerability and adaptive capacity
	Loss and retreat of glaciers would adversely impact runoff and water supply in areas where snowmelt is an important water resource.	Some social indicators have improved over the nineties including adult literacy, life expectancy and access to safe water.
	Flood and droughts would increase the frequency and lead to poorer water quality in some areas.	However, other factors such as high infant mortality, low secondary school enrolment, and high income inequality contribute to limiting adaptive capacity.
	Increase in the intensity of tropical cyclones would change the risk of life, property, and ecosystems from heavy rain, flooding, storm surges and wind damage.	Areas of particular concern are agriculture, fisheries, water resource management, infrastructure and health.
	Costal human settlements, productive activities, infrastructure and mangrove ecosystems would be negatively affected by sea level rise.	

Source: Poverty and Climate Change, 2003 adapted from TAR-WGI (2001)

According to IPCC, Brazil's agricultural production will be the second most affected in Latin America by climate change in this century. The potential consequences of climate change go beyond direct economic losses to the the social and cultural systems in those regions that depend on agriculture as the only means of survival. Agricultural adaptation programs pertaining to production alterations and financial mechanisms will be essential to mitigate the possible consequences of climate change, particularly social conflicts and potentially severe ecological problems. As agriculture is the main livelihood activity for the majority of the population it means that a great part of Brazilian population is vulnerable to climate change.

Agro-ecosystems are vulnerable to climate change in two key ways: the increased variability of temperature and precipitation, and the direct effects of global warming (increased temperature and evapo-transpiration). Although the precise agro-economic response of specific species to climate stimuli are complex and difficult to predict, in general the net impacts of climate change are expected to be negative, with lower agricultural productivity expected, primarily due to increased water stress. Additional negative impacts on agriculture may occur from the increased incidence of extreme climate events, such as violent storms.

In general, the smaller and more subsistent the agricultural operation, the more vulnerable it will be to the negative impacts on climate change. A particularly grave climate change impact on agriculture is the confluence of increased drought and high temperatures on already stressed and degraded land. The northern regions of Brazil are some of the most vulnerable to this form of landscape degradation, because of the prevailing soil and climate conditions.

Like agriculture, the water resources sector in Brazil has pronounced climate change vulnerabilities. Hydropower plants provide almost 90 per cent of the power generated in the country. If the incidence of drought does in fact increase due to climate change, the energy security of Brazil will be seriously threatened. Brazil is presently highly vulnerable to seasonal and annual hydraulic conditions, as was evident in 2001 when drought conditions forced electricity rationing because of inadequate hydropower production—a situation that may worsen due to climate change (Vujnovic, 2001). A climate-friendly power sector strategy should consider the possible impacts of climate change on hydropower production in Brazil. DREs should be seriously considered as an strategy for the Brazilian power sector, primarily because non-hydro DRE systems do not suffer the risk of hydrologic failure that centralized hydropower systems may be increasingly exposed to under climate change.

4.3 Decentralized Renewable Energy

A. Current status of DRE activities in Brazil

President Luis Inácio Lula da Silva has continued a wide-ranging reform of the Brazilian energy sector, although the full scope of reform is still unclear. In the 1990s, a new regulatory framework was established with four new agencies to reformulate and strength the government's regulatory role with emphasis on the privatization process of the sector: (1) the National Electric Energy Agency (ANEEL); (2) the National Electric System Operator (ONS) and; (3) the Wholesale Electric Energy Market (MAE), and (4) the Expansion Planning Coordination Committee (CCPE). The CCPE is part of the structure of the Mines and Energy Ministry and advises the government on National Energy Policy issues. The National Energy Policy Board (CNPE) provides market agents with indicative projections for their investment plans and establishes the transmission system expansion program. Actors in the power market agents now comprise generators, distributors (this segment includes rural electrification cooperatives) and retailers. Even though in 2003 the sector was no longer undergoing privatization, the ownership and operational structure of most companies in the electricity sector has already changed significantly. The energy industry structure consists of generators, distributors, transmission companies, marketers and suppliers.

Brazil has several companies producing electricity; most of them are independent state companies, but organized by the holding company, Eletrobrás. Other producing companies are private, e.g., one of the biggest generating companies was privatized in the State of São Paulo, but its economic health is poor. The independent power producers are allowed to generate and distribute power under previous approval from the National Electricity Agency (ANEEL).

The recently approved Law 10438 establishes clear rules for strengthening the universal service obligations of distribution concessionaires. This law created PROINFA, which encourages renewable electricity regeneration, but does not directly support it. According to this law, the Brazilian energy matrix will include 3,300 MW of renewable energy in two years, with 1,100 MW from biomass, 1,100 MW from wind power and 1,100 MW from small hydropower. Expenses related to grid connection will be borne by utilities, and not by the consumers. All utilities have to meet the deadlines to expand access to electricity, according to Tables 4.5 and 4.6.

Table 4.5 Electrification targets to be reached by utilities in their concession areas

Current coverage level in the area serviced by utility	Target year for universal access
> 99.5%	2006
> 98% and < 99.5%	2008
> 96% and < 98%	2010
> 80% and < 96%	2013
< 80%	2015

Source: ANEEL, 2003

Table 4.6 Electrification targets for municipalities

Current coverage level in the municipality	Target year for universal access
> 96%	2004
> 90% and < 96%	2006
> 83% and < 90%	2008
> 75% and < 83%	2010
> 65% and < 75%	2012
> 53% and > 65%	2014
< 53%	2015

Source: ANEEL, 2003

There are several funds in Brazil which can be applied to DRE programs. The resources of the Global Reversion Reserve (RGR) are available through Eletrobrás, to wind, solar, biomass, small hydro and thermal systems associated with small hydropower projects. The RGR can also be used for the construction of plants of up to five MW, destined to the public service of the isolated systems and to energy efficiency projects according to the National Program for Electrical Energy Conservation (PROCEL). In the case of solar energy, there is a specific program for encouraging photovoltaic panel utilization, in which Eletrobrás utilizes the resources of the RGR to directly contract utilities and permissionaires.

The diesel used in the Amazon region for electricity generation is subsided by the CCC[2] compensated by other states ("Conta Consumo de Combustíveis"—Fuels Consumption Account). Currently, nearly 1,000 power plants, mainly using diesel oil, supply electricity to isolated cities and villages in Amazon Region. More than 670 of these are less than 500 kW capacity, and in general, old, inefficient, and emit high levels of pollutants (Goldemberg, 2000).

Until recently, the CCC subsidy was provided essentially for power plants burning diesel and oil. In August 1999 however, Resolution 245 extended the benefits to electric power plants replacing fossil-fuel plants thus opening the opportunity for the use of engines operating with vegetal oils. The generators utilizing small hydropower, wind, solar, biomass and natural gas, are granted access to the subsidy account for projects which displace diesel fuel. In the case of isolated systems, these subsidies help minimize the difference between grid-connected and off-grid electricity rates paid by consumers. This incentive, which is in effect until 2022 for isolated systems, can now also benefit isolated renewable power systems by replacing thermoelectric systems that use fossil fuel. Three renewable energy projects already benefit from the CCC subsidy: a four MW Belo Monte Hydropower plant in Alta Floresta do Oeste, state of Rondonia; a 1.1 MW hydropower plant in Parecis, Rondonia; and a nine MW wood residue thermal power plant in Itacoatiara, state of Amazonas.

The Energy Development Account (CDE) was created to encourage the utilization of the states' renewable energy potential, specifically wind power, small hydropower systems, biomass, natural gas and national coal. CDE, which will also be destined to promote the extension of electric power services to the entire nation, will last 25 years and will be managed by Eletrobrás. CDE's resources will come from annual payments for the use of public facilities, from the fines levied by ANEEL and from the annual quotas paid by agents who sell power to the final consumer.

Experience with off-grid electrification in Brazil has been very limited and subject to a variety of problems regarding their sustainability. The Brazilian government and a variety of donors are supporting some initiatives designed to promote rural electrification. The main government sponsored off-grid electrification program is called Programa de Desenvolvimento Energético de Estados e Municípios – PRODEEM (managed by the Ministry of Mines and Energy), which focuses on solar photovoltaic for remote community applications, Energy Development of States and Municipalities Program – ESMAP, 2002, and the "Luz no Campo" (light in the countryside, in English) program (managed by Eletrobrás), which focuses on grid extensions (Figure 4.2).

Figure 4.2 Solar panel installed by the Brazilian Program Luz no Campo in rural houses in Amazon Region

Source: CEPEL, 2003

The Luz no Campo program was launched in December 1999, as a clear response by the federal government to the obvious standstill that rural electrification experienced after the restructuring of the power sector. Aiming to connect nearly a million rural households in the period from 1999 to 2002, Luz no Campo is the single largest rural electrification program in Brazil. Initial estimates forecast a total investment of around $1 billion, or about $1,000 per new consumer.

By September 2002, 480,000 connections had been made, and another 125,000 were in progress. A total of 823,000 new customers have signed contracts. So far, no off-grid connections have been established under the program, even though this option was contemplated. This can partly be attributed to the relatively low cost of grid extensions, averaging US$970 per connection.

Rural consumers are typically expected to pay the full costs of the connection, albeit spread over a number of years. Luz no Campo lends 75 per cent of the investment to concessionaires, under very generous conditions (a six per cent interest rate, a two-year grace period and a 5–10 year repayment period). Concessionaires finance rural consumers under similar conditions, but in some cases, the state governments provide partial subsidies.

The program's main problems are the lack of incentives to do low-cost grid connections or off-grid projects, except for a couple of specific projects in Minas Gerais, Bahia and Amazonas.

From 1996 to 2000, PRODEEM provided three MWp in PV panels to 3,050 villages benefiting 604,000 people. The total investment, financed by National Treasury funds, was $21 million. In 2000, another 1,050 systems were installed and expected to benefit an additional 104,000 people. The total budget was R$60 million for 2001, when 1,086 systems were installed and another 3,000 community systems were tendered through international bidding. The winning bid was R$37 million for equipment and installation, plus operation and maintenance for three years.

PRODEEM is a centralized project, which uses a top-down approach to identify sites and install equipment. One of the difficulties faced by the project is identifying suitable installation sites for the equipment that has been purchased in bulk. Under this program, the central government procured photovoltaic panels that were then allocated free of charge to municipalities upon demand. Rather than electrifying individual households, the program focuses on schools, health facilities and other community installations.

Table 4.7 A summary of power generation plants using new renewable energy technologies in Brazil (MME, 2003)

Decentralized generation with renewable sources (MME, 2003)

Project/program/sponsorship	State	Technology	Number	Installed capacity (kW)	Beneficiaries
APAEB	BA	PV	250		14 municipalities
COELBA					
USDoE localities	BA	PV	209		14 municipalities/18
FONDEM	BA	PV	27		27 localities
PRODEEM/Petrobrás	BA		31		
PRODEEM/Fase II	BA	PV	258		20 municipalities
Luz no Campo (implantados)	BA	PV	450		

Project/program/sponsorship	State	Technology	Number	Installed capacity (kW)	Beneficiaries
CAR	BA	PV	14,344		307 localities
CERB					
Bombeamento de água	BA	PV	180		
Luz no Campo (programados + implantados)	BA	PV			
BP Solar	BA		60		2 localities
PRONESE	SE	PV	1,400		47 localities
COHIDRO	SE	PV	47		
PRODEEM localities	SE	PV	44		44 municipalities/44
ENERGIPE	SE	wind	2		4 localities
ESCELSA	ES		2		
Guaçu-Virá	ES	PV	2(1)		1 community with 30 families
Projeto Ocaruçu – Praia de Ponta Negra – Paraty	RJ	PV/wind	1		1 community with 30 families
Morro da Previdência	RJ	PV	1	(?)	
Praia do Aventureiro (Ilha Grande)	RJ	PV			4 households/ 1 FEEMA office 1 community center (?)
ElPaso – Paraty	RJ	PV			136 households 30 public lighting 3 cooling station (18.45)
PRODEEM/RJ – Projeto GERA-SOL	RJ	PV	51		(79.00) 15 municipalities
Ilhas de Jaguanun e Itacuruçá – Mangaratiba	RJ	PV	150	(?)	
São João da Barra	RJ	PV	20		(1.06) 1 municipality
Vila de Pescadores – Ilha de Convivência – São José da Barra	RJ	PV	1		(0.12) 1 locality with 30 families
Parque Municipal Ecológico da Prainha	RJ	PV	2		(5.85)
CNBB/Pastoral da Criança	MG/BA/PI/ MA/CE	PV	32		(1.20) 29 communities
Programa Luz Solar/PRODEEM	MG	PV	672(2)		105 municipalities
COPASA	MG	PV	181		24 municipalities
Vila de Caraíva	MG/BA	PV	75		
MCH Turmalina	MG	MCH/PV	1 MCH 6 PV		(6.40) 16 households
Outras MCHs	MG/RJ/ AL/GO	MCH			
Outras MCHs(3)	MG	MCH	144		
Assentamentos Januária, Vaca Preta, Veredas	MG/RS	PV	242		
PRODEEM/Projeto Alvorada	MG	PV	246		(198.72)
COPASA II	MG	PV	100		(70.00)
Banco do Povo	MG	PV	300		
Cachoeiras do Gibão	MG	MCH	1		(20.00) 1 municipality with 22 households
Araçuaí	MG	PV	2		(2.80) 53 families
Itamarandiba	MG	PV	1		(1.10) 450 families
PRODEEM/GO	GO	PV	98		(70.53) 27 municipalities
PRODEEM/Projeto Alvorada	GO	PV	33		(23.80)
Parque da Criança, Oxigenação de Lago	GO	PV/wind	1		(1.45)
Energia Solar	GO	PV	2		(0.43)

Several incentives from foreign resources motivated the introduction of these programs, such as Global Environment Facility. The Poverty Alleviation Program (PAP), sponsored by the World Bank, was an important source of investment. The focus of the program is on the States of Northeastern Region and the drought-prone area of the State of Minas Gerais. The program provides grants to the local associations to finance their projects that have been previously approved by the Municipal Committee. Other national incentives programs, include the CCC (fuel consumption account), CDE (energy development account) and the RGR (global reversion reserve).

B. Biodiesel: An energetic alternative for small isolated communities in Boca do Acre and Pauini Municipal districts – Amazon/Brazil

With the implementation of decentralized electrification program “Luz no Campo” there was an increase in the number of rural families accessing electricity. Unfortunately this program does not include Amazonas State—located in the north—where most households still have no electrical service.

The project—Biodiesel: An Energetic Alternative for Small Isolated Communities in Boca do Acre (22,410 km^2, 26,959 residents) and Pauini (43,263 km^2, 17,092 residents) Municipal Districts—involves the production of biodiesel from vegetal oils for energy purposes and the production of medicinal glycerine soap for export. It is located in the Amazonas State, north of Brazil.

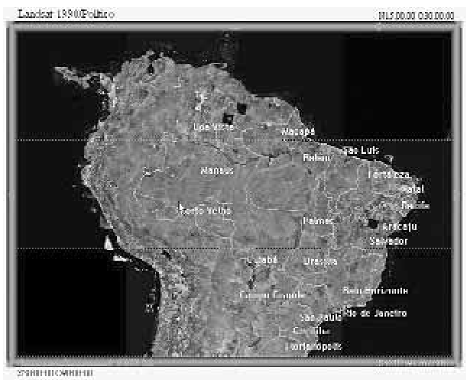


Figure 4.3 Satellite image of South America and the North Region of Brazil.

Source: INPE, 2003

The Amazonas State hosts the major part of the Amazon rainforest. It is in the extreme northwest of the Brazil territory, being formed by tablelands of Oriental Amazônia, depression of Occidental Amazônia and the Amazon River Plain. The state includes the highest point in Brazil, the Pico da Neblina (3,014.1 m). Although the Amazon water basin has the largest area in Brazil (3,904,392.8 km^2), it has the smallest hydroelectric potential (2,234.0 GWh) due to the extensive Amazon plain in the lower reaches of the river.

The Amazon Region is by far the largest region not connected to the national electric power transmission system, having centralized electric energy generation system for the biggest Amazon cities and for energy-intensive projects (e.g., aluminum production). In the 1980s, a huge natural gas deposit was found in the municipal districts of Juruá and Urucu in the Amazon State.

The Boca do Acre and Pauini municipal districts are located in the southwest region of the Amazonas State. They are among the 50 poorest Brazilian municipal districts, and it is the eighth poorest in the Amazon State. According to the UNDP (2000), the Boca do Acre and Pauini’s Human Development Indicators are 0.621 and 0.496, respectively, well below the poverty line. The electric energy and transportation is diesel-based, which is transported by ship. Delivery takes about 35 days and consumes about two litres to each litre delivered. According to the Brazilian Oil Agency, the municipal districts consumed over 3.3 million litres of diesel in the year 2001.

Figure 4.4 Municipal districts of Boca do Acre and Pauini

Source: IBGE: Cidades, 2003. Painted by IVIG/UFRJ

The Amazonas State has fewer than five million people, the second smallest population density (10 inhabitants per km^2), but the third highest annual rate of growth (more than 3.1 per cent) compared with the rest of Brazil. Thirty per cent of the population is rural; the state contributes about 1.1 to two per cent of the gross domestic product and the per capita income is around US$2,000 to US$3,000.

Figure 4.5 Rural family

Source: Paulo Coutinho, personal files, 1992

The regional economy is based on the vegetal extraction like latex (Figure 4.6), açaí, wood and nut. The region is rich in ore. The Brazilian government offers fiscal incentives to industries in Amazon State, mainly in electricity and electronics, the called "Zona Franca de Manaus."

Figure 4.6 Latex extraction and regional nuts

Source: Paulo Coutinho, personal files, 1992

The Amazonas State is not part of the National Program "Luz no Campo" for rural electrification, although and Amazonas State has only a six per cent rural electrification rate. The region does, however, have also wind and solar power potential.

Figure 4.7 State school in an isolated Amazon community

Source: Paulo Coutinho, personal files, 1992, 1992

Natural gas is an option for electric energy generation for big consumers. There is a natural gas pipeline project under study by Petrobrás (Brazilian Oil Company) and it is being explored with international partners. The conventional grid is not economically feasible for the needs of the rural population. Since other options are not available, diesel generators are used, resulting in dependence on diesel fuel, not only for the actual electricity generation, but also for the transportation of the fuel within the region, which is done almost exclusively by boat.

Figure 4.8 Boat transport

Source: Paulo Coutinho, personal files, 1992

The production of biodiesel from vegetal oils can be a good opportunity to promote sustainable development in the region by decreasing the external dependence on diesel.

In 1991, the municipal district of Boca do Acre had a program, financed by SEBRAE, to produce Brazil nut oil for soap production purposes. Unfortunately, the Brazil nut oil developed a toxin (*aflatoxin*) and the program was unsuccessful. The program closed in 1995. Nonetheless, oil production continues in Boca do Acre; two processing plants are planned: a biodiesel plant, targeting the use of vegetal oils, and second, a medicinal glycerine soap plant, aiming to use the glycerine, the by-product of biodiesel production. Biodiesel is already used in the European Community (http//www.biodiesel.com), but its implementation in an Amazon community is innovative.

The African palm trees used for feedstock production will be planted in a 50 ha of agroforestry management zone with the local labour and will employ 10 persons.

The biodiesel plant will produce biodiesel and it will be used in place of oil diesel for electricity generation, creating five jobs. Each litre of biodiesel produced also generates 200 grams of glycerine. The medicinal glycerine soap is for export, thereby, generating foreign exchange and generating five jobs.

The vegetal oil utilization for energy purposes and medicinal glycerine soap production in Pauini has clear goals for the sustainable development and poverty reduction. It is renewable and regional, strengthening the local economy and establishing access to energy.

The area to be developed for bioenergy production is currently and located at Comunidade de São Sebastião (Pauini municipal district) 51 km from the vegetal oil plant. This area was chosen because there is local community interest in the project concept

The technology to be implemented in this project will use a transterification process to transform vegetal oils into biodiesel, a technology promoted by COPPE/UFRJ, and very common in Europe. Biodiesel can be used at 100 per cent (B100) in diesel motors or mixed with oil diesel (B50, B30, etc.). There is, therefore, no need to change the present electric energy generation technologies in the region.

The basic requirement for replicating the project is the availability of degraded land for agroforestry management. According to the sustainable development criteria for regional development in Brazil (AGF, 2003 and MMA, 2003) only degraded land planted with ecologically appropriate oil tree species are permissable for this type of development. Funding for this project is being negotiated with the Eletrobrás S.A. and the El Paso Energy International do Brazil. The local NGO “Guardiões da Floresta” (Forest Guardians) is the executor and the IVIG/COPPE is the technical assistant. The local project beneficiaries are not responsible for the project co-financing.

A vegetal oil cooperative is being created to manage the project. The cooperative will be in charge of transporting the seeds to the oil plant, biodiesel plant and soap plant. The vegetal oil cooperative will manage the commercialization of the biodiesel and the soaps.

It is expected that the beneficiaries of the biodiesel electric energy are the same people who were using the diesel energy, since the project is not proposing installation of new generators.

The recovery of degraded (abandoned) areas should decrease the ecological impact promoted by former pastures activities. The project will reduce 300 per cent of the CO_2 emissions (because biodiesel is renewable and displaces the diesel required for fuel transport as well), 98 per cent of SO_x emissions and 50 per cent of the particulate matter, compared to the use of the same amount of the substituted oil diesel. However, there is a 13 per cent increase in NO_x emissions.

Ten people will be employed to manage the 50 ha of agro-forest. The biodiesel plant and the soap plant will each employ five people. Other indirect jobs that may result have not estimated. The biodiesel project will provide ancillary socio-economic benefits through the implantation of agro-forest systems, post processing of vegetal oils to biodiesel and processing of soaps with glycerine.

Since the electric energy generators will not be changed, the project cannot claim to increase energy supply, however the switch to local biofuels should improve supply reliability, and produce a relatively large carbon emissions reduction. Each litre of biodiesel used in electric generators and boat transport displaces one litre of diesel due to the diesel dependence of the area. Considering the oil used to deliver the diesel in the region, it can be said that each litre of biodiesel used displaces three liters of diesel.

The project advances sustainable development through the production of renewable energy and the creation of economic activities for small producers. The improvement in the socio-economic health of the community will enhance the community’s ability to adapt to the impacts of climate change. The success of the project depends on the the demand for soap by-products or other uses for the glycerine by-product, the success of the vegetal oil agro-forests and the quality of the biodiesel. If the project proves to be sustainable, it can be replicated in other communities and countries with oil production potential. The challenges are the as yet ill-defined harvest logistics for the vegetal oils, the operation and management of the biodiesel plant and the soap plant, and marketing the soap overseas.

The project in Pauini is not implemented yet, but there are some vulnerability aspects that should be discussed. This project will take place inside the Amazon forest where there are droughts and flood in well defined seasons (December to May – floods; June to November – drought). The excessive rain can stimulate soil degradation and interfere in local agriculture. The riverside population depends heavily on hunting and fishing, and any disturbance in the water cycle will interfere with their livelihoods. In 1997, the area had its largest flood in 40 years. Streets and homes were filled with water. This kind of project can help improve economic conditions allowing people to cope with such severe events more effectively.

The socio-economic aspect of this project is also important. According to Jose Mendonça Filho,[3] once this project is implemented, numerous isolated families will benefit from the availability of electricity. It will enable work at night, it will increase productivity and it will allow for the utilization of new technologies. However, more energy is not a guarantee of better quality of life, nor higher household income but it does enable both. Of all the forms of decentralized renewable energy possible in Brazil, biomass is the most important with respect to the mitigation-adaptation nexus of climate policy, primarily because of the huge potential for its development (primarily on degraded and vulnerable land), and its local income generation potential.

Endnotes

1 This sector is defined as the energy consumed during energy conversion processes and/or extraction processes and transport of energy products, in its final form (BEN, 2002).

2 Resolution ANEEL of August 11, 1999 (Brazilian Electric Energy Agency).

3 Personal communication.

5. Country Study: Senegal

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5.1 Introduction

The need to improve access to energy, particularly for the poor, has been at the centre of international debates in recent years. This concern, by no means misplaced, is an indication of the significant inequalities observed in the global energy situation—inequalities existing, not only between countries of the North and South, but also within the South and particularly between urban and rural areas, in southern countries.

According to estimates of the International Energy Agency (IEA),[1] nearly 1.6 billion people (about a quarter of the world's population) have no access to electricity. Moreover, in the absence of really vigorous policies, this situation will continue. As a result, by the year 2030, no fewer than 1.4 billion people will still be without electricity. In developing countries, particularly in southern Asia and sub-Saharan Africa, about four out of five of those without electricity live in rural areas. It should also be pointed out that this situation risks extending into the urban areas, since the world is getting more and more urbanized. At the global level, according to various estimates, nearly 2.4 billion people depend primarily on traditional energy, in the form of fuelwood and charcoal to satisfy their domestic energy needs; and this figure will reach 2.6 billion by the year 2030, by which time, traditional forms of energy will represent more than half the total domestic energy consumption.

An overview of the energy situation in Africa indicates that daily primary energy consumption varies between 25,000 and 30,000 kcal, which is less than the average consumption in Great Britain in 1875.[2] However, between 1980 and 1987 and between 1990 and 1997 respectively, 2.7 per cent and 3.1 per cent increase have been observed in modern energy consumption in Africa.

As assessed in the EDRC/Enda publication, energy consumption in Africa is still the lowest in global terms. In 2001, Africa's total primary energy consumption was 280 million tonnes oil equivalent (toe) of which two-thirds were concentrated in three countries—South Africa, Egypt and Algeria. Africa's primary energy consumption is approximately 10 per cent of consumption in the United States. African production of modern energy remains largely dominated by petroleum products (63 per cent in 2000), followed by coal (19 per cent), natural gas (15 per cent) and hydro electricity (11 per cent). Disparities, however, exist among the different African regions. North Africa, for instance, produces almost half the continent's petroleum and gas, with 80 per cent of these resources being consumed in northern and southern Africa. West Africa's production is largely dominated by Nigeria, which accounts for 21 per cent of the region's total production and 12 per cent of its total consumption. At the same time, it remains a net importer of energy. Africa's total electricity production (94 GWh) remains very low. Seventy-six per cent of this is of thermal origin and 22 per cent comes from hydroelectric installations, notably in east and west Africa. One important characteristic of Africa's energy situation is the huge dependence on traditional (biomass) fuels.

For countries of the West African Economic and Monetary Union,[3] energy consumption is estimated to be about 0.22 toe/household and the per-household electricity consumption is extremely low; about 59 KWh. Consumption of traditional energy in those countries is estimated to be about 78 per cent of the total primary energy consumption for 1997.

This imbalance in energy production and consumption is in sharp contrast with the continent's potential in both fossil and renewable energy resources. Figures for the year 2000, for proven reserves of coal, petroleum and natural gas are estimated at 5.7 per cent, 7.1 per cent and 7.4 per cent of global reserves, respectively. West Africa's share in Africa's total reserves is estimated at 19 per cent for petroleum, 12 per cent for natural gas and 0.1 per cent for mineralized coal. Africa's hydroelectric resources account for 10 per cent of the world's total. Biomass resources are evaluated at 82 billion tonnes, with a regeneration potential of 1.7 billion tonnes per year. It should be noted, however, that in certain regions of Africa, notably the Sahel region, there is progressive deforestation, associated with the over-exploitation of biomass resources to satisfy domestic energy and agricultural needs. Estimates of solar radiation in Africa vary between 2,000 and 2,500 KWh/m^2. (Solar energy accounts for less than one per cent of the primary energy supply.). The actual installed capacity of installed domestic solar systems in Africa (estimated at about five MWp in 1997) is also not well known.

It appears that sustainable development in Africa is seriously compromised, not only by the under-exploitation of its energy resources for its developmental needs, but also by inefficient production and use of energy. It is indeed the continent's weak economic performance, galloping poverty and the continued degradation of the environment, that have given rise to these inequalities and energy disequilibria, not to mention the unfavourable perception of energy services in the sectors of economic and social activity.

Indeed, several African countries have tried to institute various types of reforms—institutional, fiscal, economic and financial—in the energy sector, by way of diversification of energy sources, improvement of energy efficiency and promotion of renewable energy sources. These measures seek to reduce the distortions in energy services, thereby ensuring sustainable growth; competition; improvement of energy access (particularly for poor population groups) while limiting environmental degradation.

It should be noted that Senegal's energy profile and evolution very much reflect the situation existing in most African countries. A Sahelian country, with a surface area of about 196,722 km^2 and a population of around 10 million inhabitants, the country's energy situation is not very diversified and heavily dependent on biomass and imported petroleum products. Moreover, due to its rather precarious economic situation, (with a per capita GDP of US$318; HDI: 0.431; rating: 154th),[4] coupled with very challenging climatic conditions marked by drought and desertification, Senegal remains highly vulnerable to extreme meteorological events and subsequently to the effects of climate change. The policies being followed in decentralized renewable energy matters, are aimed, not only at increasing energy access for the underserved populations, in order to reduce the incidence of poverty, but also to develop alternative energy sources so as to limit environmental degradation. Those actions contribute also to the reduction of greenhouse gas emissions, and to adaptation to the adverse effects of climate change.

In this context, energy policy must to consider the following:

- The links that could be established between energy, poverty, the environment and sustainable development in Africa.
- The contribution of decentralized renewable energy in the improvement of economic performance, the fight against poverty, the attainment of sustainable development (particularly the reduction of environmental degradation), the improvement of the continent's resilience to climate change, and to the enhancement of adaptive capacity.
- The improvement of investments in energy through the flexibility mechanisms, particularly the Clean Development Mechanism.

5.2 Energy, Poverty, Environment and Sustainable Development

It has been established that energy enhances development and is a necessary component of the development of every sector of the country's economic and social activity. The level of economic performance and quality of life are largely determined by the level, amount and quality of energy services.

The poverty of energy deprivation in Africa generally, and Senegal specifically, is manifested as the predominance traditional biomass fuels, the under-utilization of modern energy sources and inefficient energy end-use systems in most countries. It has also given rise, not only to limited economic performance and exacerbated poverty but an alarming degradation of the environment as well, thus compromising any meaningful sustainable development.

The socio-economic situation of many African countries is characterized by limited GDP growth rates, low GDP units per kg of petroleum equivalent, high poverty index levels, low agricultural and industrial production, poor social indicators in the field of education, poor quality of health and water supply services, and high rates of natural resource depletion. In countries of the West African Economic and

Monetary Union, GDP growth rates decreased from 5.5 per cent in 1998, to 3.9 per cent in 2002. The poverty index varies from 37.9 per cent to 62.5 per cent. Estimated GDP units for some countries, in kg equivalent of petroleum, are as follows: Benin 2.9 kg eq; Cote d'Ivoire 4.3; Senegal 4.5; and Togo 4.7.

The strong inter-relationship among energy, poverty, the environment and sustainable development, has prompted the international community and international cooperation agencies—notably the World Bank, the United Nations Development Programme and the International Energy Agency—to incorporate this particular concern in their cooperation programs. Hence, the Millennium Development Goals, the Johannesburg plan of action and the Delhi Declaration have all echoed the commitment of African countries towards sustainable development, centred on the New Partnership for Africa's Development (NEPAD).

The convergence of these objectives, plans and programs, are at the core of strategies employed to combat poverty and achieve sustainable development. In achieving the objectives outlined in the Millennium Declaration, notably, reducing by half, the number of people living in abject poverty by the year 2015, the cross-sector solutions proposed, provide the energy sector with significant opportunities and a priority position. The Delhi Declaration on Climate Change and sustainable development[5] strengthens efforts to integrate the various climate change objectives, especially regarding energy, in national strategies on sustainable development.

Viewed from this perspective, the New Partnership for Africa's Development should be be oriented towards this vision of sustainable development. It is therefore a question, not only of finding adequate solutions to Africa's energy problems (notably energy access for at least 35 per cent of the continent's population, particularly in rural areas, within the next 20 years), but also of responding to climate change adaptation needs. The various strategic programs on the drawing board, namely, the strategic framework for poverty reduction and the priority programs on the major components of NEPAD, incorporate these concerns.

The complexity of the fight against poverty and the achievement of sustainable development, certainly justify the interest they arouse on national and international levels. However, there is the fear that this complexity could get bogged down in action plans and poorly coordinated programs. Achieving coherence in policy objectives, actions and means, is a major integration challenge, particularly in the coordination of all the donor and partners.

A. The rural energy situation and biomass dependency in Senegal

Overview of energy availability in rural areas

About 5.6 million of Senegal's people live in rural areas and this number is spread over 14,000 rural villages. Almost 50 per cent of these villages have fewer than than 250 inhabitants.

The energy situation in rural Senegal is dominated by the prevalence of the use of biomass, a limited use of modern energy sources and access to electricity. This dependency of rural areas on traditional biomass for cooking and heating, combined with extensive agricultural practices, led to the degradation of natural resources around the villages.

The energy sources such as kerosene, batteries, candles and LPG, are used in rural areas for lighting and for other commodities (radio, TV). These are expensive and less efficient compared to electricity.

The electrified villages in Senegal represent an insignificant proportion of the total villages in the country. Only 268 villages out of the 14,000 in the country are connected to the grid (less than two per cent) whereas the rate of connection to the grid in the urban areas is about 50 per cent. Per capita energy consumption in urban areas is almost twice as high as in rural areas.[6]

The Senegalese government has attached great importance to new and renewable energy sources as part of the search for solutions that would satisfy the socio-economic needs of rural areas. In this respect, many initiatives have been undertaken: installation of village solar power stations, micro power stations, standard domestic photovoltaic systems, etc.

Senegal's energy policy was formulated in response to development and environmental concerns by:

- Reforming the energy sector (liberalization of the energy sector and creation of a special agency for rural electrification);
- Promoting of a decentralized electrification systems;
- Promoting of liquefied petroleum gas (LPG) and other clean energy products to replace fuelwood and charcoal; and
- Establishing a participatory approach in forest management.

The electrification policy is targetting an ambitious and unrealistic goal to raising the urban and rural electrification to 70 per cent and 40 per cent respectively by the year 2005. The creation of the Senegalese Agency for Rural Electrification (ASER) aims to enhance the access of rural populations to electricity. The table below presents three possible scenarios for rural electrification, based on the quality of response from potential subscribers.[7]

Table 5.1 Three possible scenarios for rural electrification

Quality of response	1997	2000	2005
Weak			
Electrification level	5.0%	5.3%	6.78%
No. of subscribers	26,132	32,444	45,554
Average			
Electrification level	5.0%	6.5%	9.75%
No. of subscribers	26,132	39,729	65,552
High			
Electrification level	5.0%	15.0%	40.0%
No. of subscribers	26,132	91,095	268,933

Source: Les Défis Economiques et Sociaux de l'Electrification Rurale : A. NIANG, ASER (March 2003)

Although electricity consumption has increased moderately since 1980, only 25 per cent of the country's total population has access to electricity and only eight per cent of the rural population electrified.

Until December 1998, SENELEC, Senegal's electric power company, was responsible for rural electrification. In 1998, when SENELEC relinquished rural electrification to ASER, there were 27,000 rural subscribers, out of a national total of 330,000, with only 268 rural villages out of a total of 14,000 electrified.

Table 5.2 Electrification rate 1997–2001

	1997	1998	2001
Electrification rate (rural)	4.6%	5%	7.4%
National	26.8%	–	30.3%

Source: Les Défis Economiques et Sociaux de l'Electrification Rurale : A. NIANG by ASER (March 2003)

Rural electrification gathered momentum, following the institution of reforms in 1998, and about 650 villages were electrified by the year 2002.

The rate of connection varies from village to village, some villages having 80 per cent connection rates, while others have less than 20 per cent. The rate of connection also varies regionally. The regions of Diourbel, Thiès and Louga have 40 per cent connection rates, while in the region of Kolda, the connection rate is around 12 per cent.

Table 5.3 Connection rate from village

Region	Electrification rate	No. of homes	No. of subscribers	No. of users required for 60% electrification rate
Ziguinchor	14.0	3,020	424	1,388
Diourbel	46.8	22,700	10,620	1,064
St Louis	31.3	12,718	3,977	4,081
Tambacounda	27.0	1,503	406	496
Kaolack	26.2	6,455	1,692	2,185
Thiès	43.7	13,361	5,837	2,914
Louga	40.4	4,871	1,970	3,741
Fatick	31.8	2,261	719	649
Kolda	12.0	4,062	487	1,950
Total	36.8	79,951	26,132	18,468

Source: Les Défis Economiques et Sociaux de l'Electrification Rurale : A. NIANG by ASER (March 2003)

There are currently well over 12,000 villages in the rural areas of Senegal without electrification. These villages are characterized by their geographical isolation and small population. They are all located in the sparsely populated and arid western margin of Senegal and in the Casamance region in the south. About 8,000 of these villages have fewer than 350 inhabitants, while about 4,000 of the villages have fewer than 140 inhabitants.

The country's rural electrification strategy is outlined in ASER's terms of reference and specifies that the objective is to increase the rural electrification rate from eight per cent in 2002 to 15 per cent by the year 2005. To this end, a global program for rural electrification was drawn up for the period 2003–2022. This program, which is spread over a 20-year period, involves four five-year phases as presented in Table 5.4:

Table 5.4 Rural electrification program

Year	No. of newly electrified villages	Cumulative of newly electrified villages	No. of newly electrified homes	Cumulative of newly electrified homes	Electrification rate objective
2003–2007	3,026	3,026	163,288	163,288	51%
2008–2012	1,922	4,948	61,293	224,581	64%
2013–2017	1,609	6,558	60,680	285,261	74%
2018–2022	1,327	7,884	60,402	345,663	79%

Source: L'Electrification Rurale : A. NIANG, ASER (March 2003)

Power sector reform and rural electrification.

One of the main objectives of Senegal's power sector reform is to extend electricity supply to rural populations. To this end, one of the major innovations introduced, was the creation of the Senegalese Agency for Rural Electrification (ASER) in 1998. ASER was created in accordance with the provisions of law 98-29 of April 14, 1998, with the aim of enhancing rural electrification by providing enterprises and private operators within the sector with the financial and technical assistance needed to boost investment initiatives in the area of rural electrification. This new structural framework reaffirms rural electrification as a top priority, placing it within the context of a free market system and within the perspective of sustainable economic development. This new policy is outlined in Senegal's rural electrification plan, whose short-term objective is to raise the level of rural electrification from eight per cent in 2002 to 15 per cent by the year 2005.

The implementation of Senegal's Rural Electrification Action Plan involves the use of two modes of operation:

- *The Rural Electrification Priority Programs (PPER):*

  Following the invitation for tenders, each year, ASER has the responsibility of deciding which of the country's 18 concessions to electrify. These priority programs (PPER) are executed by private concessionary operators. This approach is usually referred to as the "Topdown approach."

A concession comprises a pool of about 5,000 to 10,000 potential household consumers, spread over a radius of 100 km.

- *Rural Electrification Projects based on local initiative (ERIL):*

  These projects make use of the "Bottom up approach," in which local operators (supervised by local organizations, NGOs, etc.) can participate in small-scale rural electrification.

There were two constraints impeding rural electrification: (1) lack of investments: (Rural electrification requires high investment flows); and (2) income derived from electricity payments was well below the cost of electricity supply. To overcome these two obstacles, the new legislative and regulatory strategies pursued by ASER involve[8]:

- attracting the participation of private investors (both national and international), as well as local associations, NGOs, etc., in rural electrification; and
- adopting a multi-technological approach, involving the use of renewable energy and technology, particularly solar energy.

Senegal's rural energy policy also emphasizes the use of renewable energy sources, such as solar energy, for rural electrification. To this end, solar energy electrification projects have been launched in the rural areas, (notably in the villages of Diaoulé and Ndiébel), for improving water and electricity supplies. In addition to the experimental centralized solar power plants in the villages of Diaoulé and Ndiébel, various projects encourage the diffusion of solar home systems. These decentralized solar home systems are designed to provide electricity to homes located in remote villages. The solar home systems provide electricity for home lighting and for operating radio and television sets. The rapid expansion of those systems in rural areas was due to the decision to locally produce all the different components of the system. Hence, apart from the solar panels and electric bulbs, all the other components were made or assembled in Dakar.

The success of the solar home systems was partly due to an efficient publicity campaign, involving the installation of demonstration home systems in public institutions, such as health centres, police and customs posts, public parks (Popenguine National Park), tourist camp sites (Palmarin) and places of worship.

Rural electrification has had a great impact on the villages that benefited. The quality of services in health centres has improved considerably, especially in child delivery. Electricity has also helped to improve the working conditions of local government employees, as well as the quality of services at police posts, border checkpoints and customs offices. The quality of education in rural schools has also improved. Children can study well into the night. Literacy classes can also be organized in the evenings.

The electrification of youth centres has also enhanced cultural activities. Income-generating activities have also been created, thus stemming the flow of people migrating to the cities. Also, by offering villagers additional facilities and services previously inaccessible to them, decentralized solar plants and solar home systems are providing the foundations of a new type of development, based on the collective management of village infrastructures.

Biomass dependency

In Senegal, traditional biomass (fuelwood and charcoal) is still the most widely used energy source for household cooking, in rural areas (94 per cent consumption of fuelwood in rural areas).

Table 5.5 Rural consumption of household energy

Type of fuel	Rural consumption
Fuelwood	94.0%
Charcoal	3.1%
LPG	1.5%
Kerosene	0.9%
Others	0.5%

Source: Senegal: An example of Three Tiers Development, J.P. Thomas, Y. Sokona (2003)

Senegal shares common energy characteristics with most African countries, including a heavy dependence on biomass, particularly in the rural areas. Biomass accounts for 57 per cent of total energy consumption. Poor households are limited to firewood and charcoal because they are unable to purchase higher quality fuels, which explains the dominance of traditional energy in both poor urban and rural households.

High biomass use raises serious problems because of its low conversion rate, high wastage and poor quality methods of production. Associated health hazards and other environmental problems are also significant, since biomass used inefficiently in cooking emits a large amount of smoke. If current population pressure continues and energy use patterns do not change, satisfying future demands will pose a major environmental problem, because of the contribution to deforestation, land degradation and erosion.

However, in the country's energy policy much emphasis is placed on preserving the environment, by progressively reducing fuelwood consumption. The forest action plan for Senegal (PAFS), stresses the substitution of liquefied petroleum gas (LPG), for charcoal and fuelwood. The LPG project, which was first launched in 1974 and relaunched in 1997, with the introduction of price subsidies, has proved extremely successful, especially in urban areas.

Social aspects and implications of energy situation in rural areas

Ligneous resources are usually exploited by rural populations for self-domestic consumption, either indiscriminately or under a formal system involving strict controls and supervision.

Fuelwood collection for domestic consumption (by simple gathering or trimming of dead wood and tree branches) is mostly undertaken by women and children. On account of the poor state of biomass resources in certain regions of Senegal, it is becoming increasingly difficult to collect wood for domestic purposes, in proximity to villages. Women are obliged to walk several kilometres in search of wood. In general, the wood they finally gather is frequently of very poor quality and largely insufficient to satisfy household domestic energy needs. This means that women have to go out daily, in search of wood. On the whole, access to good quality wood or charcoal, remains extremely difficult for many rural families, particularly on account of their poor income levels.

Moreover, the use of agricultural wastes as an energy source is fraught with difficulties related to spatial distribution. Farm wastes are most frequently used in areas where wood is rather scarce. Unfortunately, due to distribution-related difficulties, farm wastes are usually collected and burned on the farm sites during preparations for a new farming season. The average year's stock of farm waste for all of Senegal is estimated at 900,000 tonnes.

In areas where livestock farming is practised, animal wastes are collected by women and children as an alternative to fuelwood. The use of animal wastes, in such cases, is a welcome alternative due to the scarcity of wood and the difficulty in procuring wood supplies.

The exploitation of forestry resources is closely supervised by the Directorate of Water Resources and Forestry ("Direction des eaux et forêts"), following a quota system shared between forestry exploitation organizations, stakeholders operating in the sector, including forestry operators, charcoal dealers, transport operators and distributors. The charcoal dealers are generally responsible for wood cutting, carbonization of the wood, separation of charcoal from unburnt wood and packaging.

Although no precise studies have been undertaken in this area, the exploitation and use of biomass have very obvious adverse effects on the health of women and children and on the health of the charcoal dealers in particular. The strenuous physical effort required of women and children ultimately results in physical deformities, curvature of the vertebral column, spinal pains, miscarriages, premature deliveries and prenatal deformities in newborn babies. In addition, the production and use of fuelwood release carbon monoxide and smoke, which pose considerable health risks to users, since these gases and other toxic substances give rise to several respiratory diseases (bronchitis, asthma, etc.) and cancers.

In addition to the health hazards that the exploitation and use of fuelwood provoke in rural areas, it should also be noted that the lack of access to modern energy sources by rural populations seriously constrains productive activities, particularly introducing small-scale irrigation schemes in agricultural practices, improving post-farming operations, and activities connected with the preservation and processing of farm products.

B. Poverty and environmental implications of the rural energy situation

Energy poverty restricts the livelihood opportunities of the rural poor and contributes to their poverty. The environmental concerns associated with energy poverty include the ecological impacts of fuelwood extraction, deforestation, soil erosion, watershed management, typical community management approaches, biomass management, tree planting and forest management.

As mentioned, energy poverty in the rural areas of Senegal stifles the well-being and advancement of the local populations and contributes to their state of poverty. The latter can take several forms and dimensions and is usually expressed by a cruel lack of basic services, necessary for human development, such as:

- Water supply (lack of energy for pumping water from well points for domestic needs, for livestock, agro-forestry activities and for processing agricultural produce).
- Education (lack of energy for lighting classrooms; hence low literacy levels, low success rates, difficulty in retaining the services of teachers).
- Health (lack of energy for illumination of health centres and for preserving medicines and vaccines, hence poor quality of health services, high mother and child mortality, difficulty in retaining personnel).
- Transportation (inadequate transportation and circulation of goods and services, hence poor access to markets).
- Agriculture (poor diversification of agricultural products, especially dry-season crops, difficulties in preservation and processing of agricultural and fishery products).
- Small-scale enterprises or production units (use of manual labour in agricultural activities, in livestock rearing and fishing, use of inefficient traditional systems of food conservation, low productivity, precarious hygienic conditions and health hazards).

On the environmental level, the abusive exploitation of biomass for energy purposes, can produce a multitude of adverse effects.

In Senegal, forested regions (both open and closed), constitute only 20 per cent of the country's total surface area, while some 80 per cent of the country is covered by sparse savannah vegetation or open steppe. Yet, due to the country's heavy dependence on biomass, especially in the rural areas, about 300 Kha of forest is destroyed each year. Charcoal and fuelwood production (estimated at 90 million tonnes and 13.4 million cubic metres per year, respectively), impose considerable stress on the environment. Moreover, although biomass reliance is slowly decreasing, deforestation is accelerating, which implies that the other factors of deforestation: land clearing for agriculture, bush fires, over grazing, lack of rainfall, etc., are intensifying.

The intensification of land clearing activities and frequent bush fires, accelerates the degradation of agricultural land. These activities also have disastrous consequences on livestock rearing, as they destroy the vegetation cover available for livestock grazing. Since over 56 per cent of the country's population live in the rural areas, where the main income-generating activities are agricultural (crop farming and livestock raising), an increase in agricultural land degradation will ultimately mean an increase in poverty for the country's 5.3 million rural population.

The destruction of soil cover also exposes vast expanses of watershed areas to the adverse effects of solar radiation and evaporation, resulting in extensive lowering of the water table levels of underground aquifers. Wells and boreholes, therefore, become increasingly difficult to construct, since water levels descend to hundreds of feet; and the incidence of completely dry boreholes increases.

Since agricultural activity, particularly livestock rearing, requires a substantial amount of water, a decrease in water availability will impose additional stress on rural populations and aggravate their poverty.

Senegal has been pursuing an ambitious tree planting or reforestation program accompanied by community-based forest management. A study carried out by the Senegalo-German project in 2002, showed that community-based forest management is very effective in preventing over exploitation of forest resources and bush fires. In the Dankou forest area, for example, tree planting or reforestation programs were accompanied by sensitization campaigns and training programs for forest wardens and members of forest committees. Moreover, the entire village community participated in the reforestation programs and sensitization activities. Heavy fines were imposed for the destruction of forest species, in most cases on the entire village community if the culprits were not found. This resulted in a spectacular decrease in indiscriminate exploitation of forest resources. Community forest management can, therefore, be quite effective in forest conservation and in increasing the environment's resilience to drought.

Although tree planting and forest management are not typical features of biomass-dependent communities, the success of the Dankou forest experience has shown that with adequate sensitization of rural communities, tree planting or reforestation and community-based forest management can easily become inherent characteristics of rural communities.

Dankou forest, located close to the Senegalese Gambian border, covers a surface area of 3,500 ha, of which 3,000 ha is classified as forest reserve and 500 ha is adjacent forest area. A survey carried out by the PSACD program (Bah and Sall, 2002), showed that the domestic consumption of fuelwood by the local population around Dankou forest is about 3,700 M^3, of which some 15 per cent (555 M^3), are obtained from the forest.

Hence, the local population, under the supervision of the village committee and the forestry authorities, legally exploit wood from the forest both on a commercial basis and to satisfy domestic needs. It is estimated that wood resources could be extracted from the forest, to the tune of 600 M^3 of fuelwood per year, without endangering the forest. Some of the wood is transformed to coal, which is sold at Kafrine or Kaolack, surrounding urban areas.

The sale of fuelwood and charcoal brings in additional household income, which is very useful, especially during the non-farming season. It also enables the women, who are the principal fuelwood sellers, to be financially independent and to contribute towards the running of their homes.

According to the PSACD report (Christophe Chesneau, 2002), the sale of 200,000 kg of wood can fetch up to 750,000 FCFA. This profit is then shared according to the spirit of participative management, as follows:

- 120,000 towards the reimbursement of loans obtained from the local "Credit Mutuel"
- 275,000 towards the forest development fund
- 110,000 to the rural community
- 245,000 to wood cutters or collectors

Participative development, according to the PSACD study, seems to be the best model for sustainable forest management in developing countries. With its low-cost advantage, this model reduces the incidence of forest fires, checks clandestine exploitation and prevents the irresponsible destruction of forest resources.

C. Vulnerability of rural communities to climate change impacts

According to the Dutch National RESEARCH Program on Global Air Pollution and Climate Change[9] an analysis was made of the climatological evidence for changes, looking at the 1960–2000 data and comparing them with 1930–1960 figures for West Africa. From the data, the following can be seen: large fluctuations in rainfall including a number of years with extreme risks of agro-climatological droughts; drastic deterioration of rainfall/evapo-transpiration and southward movement of boundaries between humidity and sub-humidity, sub-humidity and semi-aridity, and semi-aridity and aridity; increase of agro-climatological droughts; start of the monsoon season becoming less predictable and generally later; etc.

The initial first national communications on climate change showed that Africa, mainly West African countries, contributed the least to the emission of greenhouse gases, but they are among the most vulnerable regions to climate change. GHG emissions for Senegal are presented below:

Table 5.6 GHG emissions for Senegal

Sectors	(Gg CO_2) 1994
Energy	3,788.6
Industrial processes	345.5
Waste	2,226.2
Agriculture/livestock	2,957.6
Land use change	-5,997.0
Net emissions	3,321

Source: Senegal's First National Communication

West African countries have the least capacity to adapt to the effects of climate change, due to the extreme poverty of the population, frequent natural disasters such as droughts and floods, and an agricultural sector heavily dependent on rainfall. The main impacts of climate change will be on water resources, food security and agriculture, natural resource management and biodiversity, and human health.

Decreased precipitation in semi-arid and arid parts of Africa resulting from climate variability and climate change could be a problem for future water resources, and will affect the levels of water storage in lakes and reservoirs. These changes in precipitation concern the main river basins such as the Niger River Basin, the Senegal River Basin and the Gambia River Basin, where the main West African hydroelectric dams or hydroelectric potentials are located.

The populations dependent on biomass energy will be impacted by the decrease in forest productivity. Desertification will be exacerbated by reductions in average annual rainfall, runoff and soil moisture, especially in southern, North and West Africa. Increases in droughts, floods and other extreme events would add to stresses on water resources, food security, human health and infrastructures, and will constrain development in Africa.[10]

At the country level, the impacts of climate change described in the first National Communication in Senegal showed that agriculture is greatly influenced by the setbacks of Sahelian climate conditions, and is also vulnerable to the adverse effects of climate change. Senegal's agriculture is also dominated by rain-dependent crops and a low level of private investment. For these reasons, the country's agricultural production is extremely vulnerable to even moderate changes in climate conditions. Millet and groundnut cultivation occupies 89 per cent of cultivated land surface area, providing 82 per cent of the total agri-

Figure 5.1 Children at PV powered water pumping station (PV panels visible in the background)

Source: ENDA

Figure 5.2 Woman and child at PV powered livestock watering station

Source: ENDA

cultural production. Climate forecasts for 2025 suggest a reduction in agricultural production; whereas, demographic growth and increased urbanization will increase the food deficit. The production of cereal crops, which are especially sensitive to water deficits, are extremely vulnerable to climate change. The provision of potable water and the majority of agricultural activities are heavily dependent on the exploitation of underground water supplies. However, the water resources sector is seriously threatened by a drastic fall in precipitation levels, recorded over the last few decades.

The adaptation strategies in key sectors assessed in Senegal are the following:

Table 5.7 Adaptation strategies for Senegal

Energy	Water resources	Agriculture
• Introduction of renewable energy in electrification policies (decentralized electrification, decentralized solar energy pumps, village electrification, decentralized electrification systems for administrative and social community infrastructures • Energy efficiency in the industrial and housing sectors • Sustainable and participative management of traditional energy	• Provide sound management of surface water resources (construction of earth dams) • Protection and sensitisation of local population (application of a national sanitation plan)	• Implementation of strategies to combat drought (extension of cultivated lands, sound water management, soil regeneration, selection of drought resistant varieties, intensification of agriculture and improvement of agricultural production).

Source: Extracted from Initial National Communication

5.3 Decentralized Renewable Energy

The interest accorded to renewable energy in sustainable development and in the fight against poverty, particularly in climate change mitigation and adaptation, contrasts sharply with the marginal position it occupies in the energy balance of many countries; and in spite of its impressive potential. With the support of various bilateral and international partners, many African countries have introduced research and experimental renewable energy programs, particularly photovoltaic systems, for purposes of illumination, domestic cooking, water supply, food conservation, etc. The World Summit on Solar Energy brought renewed hope regarding the promotion of renewable energy, and the Global Environment Facility (GEF) and non-governmental organizations have been providing some support.

Modern biomass technology have been applied successfully in many isolated initiatives. In countries affected by desertification, the emphasis has been placed on improving the efficiency of biomass consumption (for example, improved stoves).

Measures geared towards poverty reduction, rural development and environmental management, justify the proliferation of renewable energy. Moreover, difficulties associated with connecting rural communities to the national electric grid and the degradation of biomass resources, have largely contributed to the emergence of renewable energy. However, without a massive diffusion of renewable energy technology, one wonders whether the latter's impact will not remain very limited, both in terms of the reduction of poverty and environmental conservation.

Undoubtedly, renewable energy contributes towards improving the living conditions of disadvantaged population groups, by providing access to basic social services, diversifying production in rural areas (market gardening, small-scale industries and enterprises, individual or family-run) and by reducing the pressure on biomass resources. Nonetheless, as past experience with renewable energy has shown, access to this energy source, for poor communities in rural areas, will have to be envisaged as part of a range of energy options, which ensure the provision of reliable, economically viable, ecologically sustainable and socially acceptable energy services. Promotion of renewable energy has been undertaken in a very selective way, based on available technology. Some technologies based on modern biomass sources, wind energy and hydro-electricity, have been successfully explored. The energy services offered, have had very little impact on productive activities in rural areas, and as such, have contributed very little to poverty reduction. In cases where appliances were financed from project funds, it will be difficult to assess their accessibility, in the absence of subsidies and other facilities.

This renewed interest in decentralized renewable energy technology, within the contexts of sustainable development, poverty reduction, climate change mitigation and adaptation, raises a number of still unanswered questions, including the following:

- Is decentralized renewable energy a reliable option in addressing the challenges of poverty, sustainable development and climate change mitigation and adaptation?
- Which indicators are the most relevant or pertinent in evaluating the impact of decentralized renewably energy on poverty reduction, sustainable development, and climate change mitigation and adaptation?
- What constraints should be removed in order to make decentralized renewable energy more accessible and competitive? And also, what have been the co-benefits experienced in cases where DREs have been successfully implemented?

A. Current state of DRE activities in Senegal

Senegal's solar and wind energy potentials are relatively high. Annual average estimates for solar radiation and insulation are respectively 2,000 KWh/m^2/year of global horizontal radiation and 3,000 hours of annual insolation. Wind energy is concentrated along the coastal belt, between Dakar and Saint Louis. Average exploitable wind energy is estimated at 1.5 KWh/m^2/day. Also, the water table is located at very low depths, favouring the installation of wind pumps.

An important research and development program on renewable energy sources had been set up in the past, with the help of financial backers and with the participation of several public and private stakeholders. Areas of intervention included: mineralized water production, water pumping activities and production of decentralized electric power. A number of infrastructure projects were completed, including: several photovoltaic power stations (of about 50 KW capacity, installed in 1991, and a 550 KW capacity station installed in the Sine Saloum, in eastern Senegal, Casamance); photovoltaic solar pumps (about 50 in number, of installed capacities between 1.7 to 2.4 KW); and about 1,000 solar household systems, including 800 of between 25 to 50 KW installed capacity, under the Senegalo-German cooperation program and 200 currently on a project pipeline. In addition, a private sector photovoltaic distribution enterprise was set up.

In addition to the photovoltaic solar and wind systems, other initiatives promoting efficient biomass use, notably, the use of agricultural and agro-industrial waste, have been undertaken. Agro-industrial wastes (peanut shells, bagasse), are used to provide heat and electricity in industrial units (SONACOS, a Senegalese vegetal oil manufacturing company). Various projects involving the processing of peanut shells and rice husks into charcoal briquettes are under way (NOVASEN, in the region of Saint Louis).

Most of these initiatives came about from industrial research and development. However, today, it is evident that environmental and economic preoccupations, under the framework of the fight against deforestation, desertification and poverty, constitute the most important motivations. Moreover, these concerns have been accorded priority positions in national and sectoral policies and considerations.

B. Case studies

Case 1: The German/Senegalese Photovoltaic Solar Energy Project, at Diaoulé and Ndiébel.

General context

The German/Senegalese Photovoltaic Solar Energy Project was launched in 1987 and lasted for five years. The principal aims of the project were:

- to test and disseminate photovoltaic systems;
- to contribute to improving the water and electricity supplies of rural communities; and
- to adapt photovoltaic systems to local conditions.

Under the terms of the project, two village solar power stations, as well as domestic photovoltaic systems (Solar Home Systems), were installed at Diaoulé (a village situated 150 km from Dakar, within the Diaoulé Rural Community, in the region of Fatick); and at Ndiébel (situated 157 km from Dakar, within the Ndiébel Rural Community, in the region of Kaolack). The first phase of the project took place between 1987 and 1992, during which, the following systems were installed:

- two village power stations of 22.8 and 19.8 kWp at Diaoulé and Ndiébel;
- four mini-power stations of 150 to 1,230 Wp for isolated health centres;
- six solar PV pumping systems (from 0.1 to 1.3 kWp), with a total installed power of 21.3kWp; and
- more than 1,250 Solar Home Systems (household lighting systems).

Diaoulé and Ndiébel are situated in the central groundnut producing region of Senegal, which is characterized by a northern Soudanian climate (average annual rainfall 600 mm), with two contrasting seasons:

- The dry season, which extends from October to June, is characterized by dominant east-Northeast winds, occasionally charged with dry dust (harmattan).
- The rainy season (or hivernage) extends from July to mid-October and is characterized by light rainfall of very short and irregular duration.

The region's vegetation consists of an open steppe, composed of baobab (Adasonia digitata), tamarins (Tamaridus indica) and acasias (Acacia albida). The vast expanse of very flat, low lying plains, with hardly any variation in altitude, is located within an extensive sedimentary basin.

Diaoulé and Ndiébel[11]

Diaoulé and Ndiébel both lie within longitudes 16° and 16.5° west; and between latitudes 14° and 14.5° north. Diaoulé's population of fewer than 1,500 is composed of 46 per cent adults and 54 per cent youths under 18. Peuls, make up 63 per cent of the population, the rest being Serers (18 per cent) and volofs (17 per cent). Ndiébel's population of 1,018 is distributed among about 137 households.

Technical characteristics

The Diaoulé photovoltaic power station (voltage 220 V/50 Hz) was put into service in May 1989 and has a daily output of around 70 kWh. In December 1995, it was completely overhauled, with a new capacity of 22.88 kWp. In contrast, the PV station at Ndiébel, put into service in 1990, has a daily output of about 58 kWh. It was also completely overhauled in May 1996, giving a capacity of 18 kWp.

The photovoltaic power installation at Diaoulé is composed of the following elements:

- 520 photovoltaic modules.
- One 30 kW SUN POWER continuous current electronic regulator.
- A storage mechanism composed of 150 Hagen elements of 2V voltage and 690 Ampere-hours (Ah) capacity.
- One SUN POWER rectifier, composed of three modules, with a normal power output of 19.8 KVA.
- A two-phase seven-km long distribution network, of 220 V and 250 Hz, provided with six leads:
  - four leads for the village,
  - one lead for public lighting,
  - one lead for the power station.

The photovoltaic installation at Ndiébel is composed of the following elements:

- 360 photovoltaic modules of capacity 18 kWp
- One 20 kW SUN POWER continuous current electronic regulator
- A storage mechanism, composed of 150 Hagen elements of 2V voltage and 690 Ah capacity
- One SUN POWER rectifier, composed of three modules, with a nominal power output of 15 kVA
- A two-phase seven km long distribution network of 220V and 250 Hz, provided with six leads:
  - four leads for the village
  - one lead for public lighting
  - one lead for the power station.

Table 5.8 Summary of the principal characteristics of the solar power stations at Diaoulé and Ndiébel

Designation	Diaoulé	Ndiébel
Modules	A.E.G. PQ 10/40	A.E.G. PQ 40/50
Type	Poly – Sic	Poly – Sic
Number of modules	560	400
Module capacity	38.4 WC	50 WC
Installed capacity	21.5 kWc	19.8 kWc
Monthly production	2,100 kWh	1,900 kWh
Batteries	300/690 Ah in 150 elements	100 V/690 Ah in 150 elements
Ondulators	20 KVA/220 V/50 Hz	15 KVA/220 V/50 Hz
Low voltage network	220 V/50 Hz	220 V/50 Hz

Source: Centrales Solaires Photovoltaiques : Rapport Annuel d'Exploitation (1996)

In Diaoulé, the power station, distribution network and domestic solar installations (Solar Home Systems) required an investment of US$567,000; (an investment of US$550,000, in the case of Ndiébel), which was financed by the project, through the German government.

To enable every household to gain access to electricity, the project set the connection fee at about (US$6) for households and (US$20) for commercial establishments. This included the cost of two light bulbs, switches, plug sockets, connecting cables and a meter. Thanks to the low charges, almost all potential consumers promptly paid to be connected. A two-bracket price scale was put into effect, to avoid overloading the power station's capacity and to recover the operating costs. Hence, for the first 20 kWh consumed per month, the charge was (US$0.4) per unit (the same price charged by Senelec for low consumption). For every kWh above 20 kWh, the charge was (US$0.5).

Solar Home Systems (SHS)

Each domestic Photovoltaic system is made up of one 50 WP Photovoltaic cell, a 50 Ah battery, a regulator, four incandescent light bulb fittings of 10w/12v, and a plug socket for radio or television. To popularize the domestic photovoltaic system, the project explored the possibility of local production of the different components of the system. Hence, apart from the solar panels and bulbs, all the components of the photovoltaic system are made or assembled in Dakar.

Local production enabled the project to reduce costs and obtain a tax and duty-free price of around US$600 for a standard system. More than 400 domestic systems have been installed. These provide electricity for lighting, household radio and television and for health centres, maternity units, tourist resorts, etc.

The Prices of components of Solar Home Systems before and after the Devaluation (in USD and CFA "local currency") are presented below:

Table 5.9 Cost of solar home systems before and after the devaluation

Prices of components	1990 prices (pre-devaluation)		1994 prices (post devaluation)	
Solar panels	98,000 CFA	327 USD17	153,000 CFA	255 USD
Accumulator (battery)	000	57	28,750	48
Regulator	7,000	23	12,950	22
Metallic support	8,000	27	16,000	27
Light bulbs (4) and switches	9,600	32	47,800	80
Installation facilities	15,400	51	25,760	43
Total	155,000	517	284,260	474

Source: Centrales Solaires Photovoltaiques : Rapport Annuel d'Expolitation (1996)

Management institutions

Prior to the final handing over of the solar power installations to the national utility SENELEC, the project was responsible for the overall management of the installations. A village management committee was established for each power plant, to deal with meter reading and collection of payments. This committee was also responsible for electricity connections, the suspension of electricity supply and the establishment of payment moratoriums. The involvement of villagers in the management process had a twofold objective: to ensure responsible subscribers and to reduce management costs.

On the completion of the project, a convention of collaboration was signed between SENELEC; the Solar Energy Project (represented by the Directorate of Science and Technology Affairs - DAST); the German Cooperation GTZ and the rural communities of Diaoulé and Ndiébel. Under the terms of the convention, SENELEC was put in charge of the management and maintenance of all the photovoltaic power installations. Thus the transfer of the management and maintenance of the solar power installations to SENELEC, ensured the involvement of the private sector and avoided the necessity of creating new management institutions.

Socio-economic and socio-ecological impacts

Access to electricity has improved living standards in Diaoulé, in many ways:

- Electricity has become the primary source of energy for lighting, as well as for operating radios, cassette recorders, television sets and refrigerators. The number of electrical items in households is increasing (one television set for every 10 households, as opposed to one set per 40 households prior to electrification).
- Efficiency at the health centre also has also improved with lighting conditions for carrying out minor surgical operations, infant deliveries, etc. Four micro power stations of 150–230 Wp were installed in health centres located in isolated zones. With the assistance of past projects, the health centre at Diaoulé was provided with a refrigerator for preserving vaccines.
- Greater access to information and knowledge, through the information media (television, radio, etc).
- Refrigeration and preservation of food in homes have brought additional comfort.
- With the help of electricity, entertainment such as cultural dancing, traditional wrestling, etc., are now easier to organize.
- Income-generating activities, such as rice milling, production and sale of ice blocks, etc., have been created.
- Diaoulé is better illuminated. This protects inhabitants from scorpion and snakebites, which were quite common during the rainy season.
- Reduction of fire outbreaks, caused by the use of candles and kerosene lanterns.

- Electrification of homes in Diaoulé has enabled students to study for longer periods. This has improved the quality of education.
- Electrification has completely changed the general outlook of the village, making it more attractive and lively.

Household uses of electricity at Diaoulé and Ndiébel

A survey carried out just after the start of the project showed that lighting remains the principal use of the electricity supplied (over 90 per cent of households in Diaoulé and over 98 per cent of households in Ndiébel). This is closely followed by radio and television and 42.8 per cent of households in Diaoulé and 32.1 per cent of households in Ndiébel use it to operate radio cassette recorders. Very few homes use electricity for refrigerators, because they simply cannot afford them. The use of electricity to operate appliances such as air conditioners, electric irons and water heaters is strictly forbidden.

Table 5.10 Household uses of electricity at Diaoulé and Ndiébel

	Diaoulé	Ndiébel
Uses of electricity	% of households	% of households
Lighting	93.3	98.2
Radio	42.8	32.1
Television	9.3	7.2
Refrigeration	2.1	2.4
Ventilation	4.3	0.6

Source: Suivi des Impacts socio-économiques des Centrales Photovoltaïques de Diaoulé et Ndiémbel ENDA T.M. 1993

Variation of electricity consumption at Diaoulé

The highest level of electricity consumption is attained during the traditional wrestling tournament period (between December and February). The tournaments begin late in the night and usually continue into the early hours of the morning.

Table 5.11 Electricity consumption in Diaoulé between 1991 and 1993 (in kWh)

D/J 91	F/M	A/M	J/J	A/S	O/N	D/J 92	F/M	A/M	J/J	A/S	O/N	D/J 93
1,500	2,100	2,400	2,000	2,050	1,500	2,600	2,300	2,400	1,500	1,750	2,500	2,400

Source: Suivi des Impacts Socio-économiques des Centrales Photovoltaiques de Diaoulé et Ndiébel ENDA TM (1993)

Variation of electricity consumption in Ndiébel

The highest level of electricity consumption is attained during the vacation period in July and August, when school goers and expatriate workers return to the village to spend their vacation and there is a corresponding increase in socio-cultural activities.

Table 5.12 Electricity consumption in Ndiébel between 1991 and 1992 (in kWh)

J/F 91	M/A	M/J	J/A	S/O	N/D	J/F 92	M/A
–	2,610	2,800	3,953	2,000	1,500	2,200	1,750

Source: Suivi des Impacts Socio-économiques des Centrales Photovoltaiques de Diaoulé et Ndiébel ENDA TM (1993)

The impact of electricity on the consumption of other sources of energy

Effect on biomass (fuelwood) consumption

Electricity has not had much impact on fuelwood and charcoal consumption, as electricity is rarely used for cooking. Over 80 per cent of the electricity supplied is used for lighting.

Effect on kerosene consumption

Prior to electrification, kerosene lanterns were widely used for lighting. The average monthly consumption of kerosene was 3.5 litres for Diaoulé and 2.5 litres for Ndiébel. Several follow up surveys undertaken in Diaoulé and Ndiébel, have shown that electricity has effectively replaced kerosene lanterns and candles as the principal source of energy for lighting.

Impact on the use of dry cell batteries

Before the advent of electricity, car batteries were widely used in Diaoulé and Ndiébel for the general lighting of homes and community infrastructures; and for operating small appliances, such as rice mills, welding machines, etc. The smaller dry cell batteries were used for operating radios and cassette recorders. However, electricity has largely replaced battery use.

Who is benefiting from increased energy supply?

The sectors benefiting from increased energy supply are:

Table 5.13 Electricity consumption by sector (in kWh): Diaoulé

Period	Jan 1991	Feb/Mar	Apr/May	Jun/Jul	Aug/Sep	Oct/Nov	Dec	%
Commerce	138	195	237	234	246	170	255	12.2
Community services	147	168	140	141	145	139	172	7.2
Households	1,143	1,729	1,970	1,497	1,603	1,068	2,202	80.0
Total	1,426	2,092	2,347	1,884	1,994	1,377	2,628	100.0

Source: Suivi des Impacts Socio-économiques des Centrales Photovoltaiques de Diaoulé et Ndiébel (1993)

Table 5.14 Electricity consumption by sector (in kwh): Ndiébel

	J/F 91	Mar/Apr	May/Jun	Jul/Aug	Sep/Oct	Nov/Dec	J/F 92	%
Commerce	400	226	219	482	283	168	239	8.0
Community services	1,009	357	261	331	297	260	391	15.5
Households	4,892	2,027	2,306	3,090	1,546	1,031	1,810	76.5
Total	6,301	2,610	2,786	3,953	2,126	1,459	2,240	100.0

Source: Suivi des Impacts Socio-économiques des Centrales Photovoltaïques de Diaoulé et Ndiébel (1993)

Impact of electricity consumption on sector

The consumers of the electricity supply fall into three broad categories: domestic, commercial and community services.

At Diaoulé, the tertiary sector (commerce and small enterprises), represents only 12 per cent of total electricity consumption. The domestic sector remains the dominant consumer, representing about 80 per cent of total electric energy consumption. The average household consumption is however rather low (8 kWh per fortnight).

Although commercial activity at Ndiébel is comparatively more intense than at Diaoulé (there is a very large and famous market at Ndiébel and Monday is a very busy market day which attracts traders and shoppers alike), this is not reflected in electric power consumption, due to the extensive use of gas oil in operating appliances such as milling and welding machines. This explains the low share of the commercial sector in the total electric energy consumption. (eight per cent). Electricity consumption in the community services sector (youth centres, heath centres, schools, etc.) illumes limited to lighting. In actual fact, the Catholic mission at Ndiébel, (which includes a boarding school, church and training centre), is the main consumer of the community services sector (up to 60 per cent of the electric energy consumed).

Impact of electricity on agriculture

The inhabitants of this region are mainly peuls, for whom cattle-rearing is a a way of life. Since cattle watering requirements are enormous, this form of agricultural activity has been greatly enhanced by the marked improvement of water supply, following the introduction of the solar pumps. Cattle herds no longer have to migrate to other regions in search of water and fodder. Cattle dung is, therefore, available in greater quantities for use as fertilizer in agriculture.

The region is Senegal's principal groundnut basin. More than 90 per cent of the households are engaged in groudnut production. Increased water supply and the marked improvement of living conditions brought about by the introduction of electricity have encouraged many youths to remain in the village and participate in agriculture, which has in turn improved local agricultural productivity.

Impact of electricity on commercial and small-scale industrial activities

Commercial and small-scale industrial activities have intensified, especially in Ndiébel, where there is a large market. The availability of electricity has encouraged the growth of income-generating activities such as tailoring, hairdressing, furniture making, welding, etc. No fewer than 11 restaurants and nine shops were opened in Ndiébel during the first two years of electrification.

The effect of DRE on the environment

The increase in household income has helped to relieve the burden on biomass. Many households can now afford either charcoal or butane gas for cooking. Thus, inhabitants of the two villages have not only increased their energy consumption, but have also diversified their sources of energy and decreased their dependence on biomass. Families have been able to use their time to generate income and have been able to send their children to school.

Climate change relationship

No specific evaluation has been made of the greenhouse gas emissions reduction potential of the photovoltaic solar power stations at Diaoulé and Ndiébel. However, on the basis of the capacities of the two stations (128 kWh/day or 46,720 kWh/year, and considering the fact that the production of one MWh of electricity by a thermal plant of equivalent capacity releases 0.73 tonnes of CO_2, one can estimate the level of CO_2 emissions avoided by the solar stations at Diaoulé and Ndiébel to be about 34 tonnes of CO_2 per year.

In addition to the amount of CO_2 emissions avoided, the solar plants contribute towards reducing the country's vulnerability to climate change and reinforce its capacity for adaptation. Also, the association of the solar plants with water pumping technologies, helps to increase the availability of water resources, which also facilitates tree planting and reforestation activities, and the development of vegetable garden crops. The community should, therefore, be more resilient to climate stress.

Overall assessment

The German/Senegalese Solar Energy project presents an important and original case study for many reasons. The interest in analysing this project is prompted by several factors:

- The project has achieved a wide distribution of Solar Home Systems in Senegal (By 1994, more than 1,300 units had been distributed).
- It includes the local production of some components of the Solar Home Systems or PV-kits. The regulators and accumulators are manufactured in Senegal by locally-based companies.
- A lot of importance was attached to the socio-economic follow-up of the project, which enabled the development of specific dissemination techniques. It also enabled special energy billing procedures to be designed, produced and tested.
- The involvement of the private sector ensured an autonomous future after the project.

At the end of the project, specific recommendations were made to ensure the project's durability, and concerned ensuring the local populations were engaged in managing the equipment, and ensuring the adequate provision of of spare parts for the equipment in sufficient quantity.

This project has been successfully repeated in Dionwar and Niodior, under the Japanese/Senegalese Solar Energy Project. This involved the establishment of PV stations and dissemination of Solar Home Systems for domestic lighting. The objective is to install 3,000 Solar Home units per year. The Senegalese/Japanese project also includes the installation of PV water pumping systems.

The rural electrification program in general greatly relies on its pilot projects. Today, several solar power piolt projects are either under way or under negotiations with ASER, under the framework of energy sector reforms.

Case 2: Sustainable agro-forestry practice in Senegal: ENDA SYSPRO experience

General context

ENDA SYSPRO is a team of the organization Environnement et developpement du tiers monde (ENDA-TM), which has developed an ecologically-sustainable agro-forestry practice in Senegal. The SYSPRO projects are located some 50 km from Dakar, at Sebikotane, Djebi and Daga. Each project consists of about five hectares of cultivated land. The Sebikotane project has been in operation since 1990, while the Djebi project (directly adjacent to that of Sebikotane), came into existence in 1991. The Daga project was initiated in 1993.

The Sébikotane-Ponty region, contains an agricultural farm of more than 10,000 ha, of which 2,000 ha are under active cultivation. This region provides 80 per cent of Senegal's vegetables export. Hundreds of farmers have moved into the area, following the construction of a secondary road track, which has helped to provide access to more than 8,000 ha of farmland. The SYSPRO production system is implemented by agricultural entrepreneurs, whose production of fruits and vegetables are meant for the local markets and for export.

Technical characteristics

The agriculture practice involves drip irrigation and the planting of hedges at the boundaries of agricultural farms to form a wind break (wind shelter belt), which also serves as a storage system for biomass from crop residues undergoing composting. The practice makes extensive use of composting to improve soil macro-porosity and fertility, resulting in increased production of various crops and vegetables for the local markets and export.

One can notice that the key agro-ecological features (Venema *et al.*, 1997) of the SYSPRO system include:

- heavy reliance on ecological benefits of associative cultures (inter-cropping);
- integrated agro-forestry through extensive wind break development;
- composting;
- simple irrigation technology;
- modest use of fertilizers and insecticides;
- reliance on labour-intensive, rather than resource-intensive cultivation to ensure optimal production levels; and
- establishment of nurseries with an emphasis on producing diverse species.

Management structure

The production systems that were established, benefited from the technical expertise (training courses) and the administrative and financial assistance of ENDA SYSPRO. ENDA SYSPRO provides organizational assistance, notably in the establishment of cooperatives or associations, either in terms of developing skills in purchasing seeds and in transportation of produce, or skills necessary in defending their economic and social interests.

Agricultural stakeholders are operators who invest in agricultural production as entrepreneurs. They are given latitude to develop initiatives, with respect to the management systems that should be put in place. At the same time, they can solicit advice from ENDA SYSPRO.

Socio-ecological and socio-economic impacts

The SYSPRO agro-forestry projects, while considered as agricultural development options to combat deforestation, drought, poverty and to enhance a productive and intensive export-orientation, could be also considered as a policy options for water resources management and climate change adaptation.[12]

The socio-ecological aspects of the SYSPRO program concern the improvement of soil fertility and the reduction of soil erosion. It also maintains biodiversity by reducing deforestation and fragmentation of the landscape as well as by reducing the need for water for irrigation.

A comparison of the water consumption (at field level) of a conventional irrigated mixed vegetable system and the intensified SYSPRO system, shows the potential this system has for year-round production. The system's ecological rehabilitation ability is closely related to the year-round maintenance of a cover crop (Venema *et al*. 1997).

The SYSPRO agro-forestry program has never undergone any comprehensive socio-economic or environmental evaluation. However, on the basis of information received from project proposals,[13] it is evident that the system generates considerable socio-economic and environmental advantages in terms of:

- Improvement of food security, by virtue of the variety of crops grown (vegetables, fruits). The volume of fruits and vegetables produced and marketed is estimated at 10 t/ha.
- Generation of income for agricultural entrepreneurs and other economic agencies (the state, transportation operators, transit operators, local distributors, etc). On average, producers realize a profit of about US$500 per tonne of fruits and vegetables sold.
- Creation of permanent and seasonal employment: each hectare of farm land employs an average of five people. About 50 women are required to harvest one hectare of runner beans. Moreover, the production system could help check rural exodus and promote migration from urban to rural areas.
- Increase of agricultural productivity and application of innovative technology (various high technology agricultural activities, including biotechnology transfer, have been developed at ENDA SYSPRO, to improve food security and measure carbon sequestration). In addition, innovations introduced into the field of irrigation harvesting, refrigeration, transportation and marketing should contribute towards the modernization of agriculture and agricultural entrepreneurship.
- Improvement of the quality of life of rural populations, through the establishment of production (agricultural tracks) and social infrastructures (a training centre has been set up for Senegal and other sahelian countries to replicate such farming systems).
- Rehabilitation of the environment. The cultivation of hedges could greatly modify the microclimate, mitigating wind and water erosion and contributing to reforestation and environmental regeneration. A 10 ha farm could be divided into 20 plots of 0.5 ha, to facilitate the planting of perennial trees.

The SYSPRO system should be the subject of further field research from agronomical and socio-economical viewpoints, as well as for the potential of biomass production for modern energy purposes. Introducing electricity is important for intensifying production (e.g., irrigation pumping, lighting, refrigeration, food process, etc.). The SYSPRO system has potential for expanding forestry component to produce feedstock for bioenergy.

Climate change relationship

The SYSPRO agro-forestry system reduces GHG emissions by: avoiding deforestation and promoting sequestration of carbon in hedges and soils; and by replacing fossil fuels with sustainably harvested firewood. It also helps to reduce vulnerability to climate change.

Internal assessments, undertaken by ENDA SYSPRO, indicate that the sequestration capacity of the agro-forestry systems is between 10 to 15 tonnes of carbon per hectare.

To estimate the sequestration capacity, the Micrcal Origin Version 6.0 model was used, which established the correlations between dry aerian biomass, dry root biomass and the diameter at chest level. A specimen sample of 30 whole trees (including the aerial or trunk portion and the roots portion) was collected. The following measurements were made: measurement of the diameter at chest level;. measurement of the weight of the aerial or trunk portion; and, measurement of the weight of the roots portion. The dry biomass weight for each tree was then calculated, using the average biomass water content.

Overall assessment

The success of the SYSPRO projects has been attributed to the windbreak/composting maturation, as well as the continuance of the extension services. Composting costs are estimated to be only about 25 per cent the cost of fertilizers.

However, financial constraints still continue to limit production to only half of the optimal production levels. SYSPRO's involvement is limited to technical and occasional credit extension. Lack of short-term credit has been cited as the greatest single impediment to achieving optimal production levels.

The SYSPRO projects at Sebikotane demonstrates that irrigated agro-ecosystems can catalyze environmental rehabilitation, providing gainful employment, while maintaining economic viability. One reason for its success could be the fact that the projects evolved as GIE (Economic Interest Group) projects, completely independent of all social and traditional rural organization. GIE projects have more freedom to operate and innovate, completely outside the traditional rural political system. This is in contrast to PIV projects (Périmètres Irrigués Villageois), which have to respect traditional village political norms in their irrigation design and management practices.

The SYSPRO initiative has conducted the extension of this experience to Tambacounda with the support of the Canadian International Development Agency (CIDA). The project covers over 1,000 ha, and is by far the largest SYSPRO project yet to be developed. The project offers an excellent opportunity to establish a test field for detailed agronomical engineering studies. CIDA's involvement as the principal funding agency also provides a convenient avenue for collaborative research.

A bioenergy component can be included in SYSPRO energy. Actually, only firewood is exploited. There are possibilities to grow bioenergy crops and windbreak species producing fuel or ethanol for electrical generation and diesel engines.

The other projects initiated are:

- The Tambacounda project also offers research opportunity on the sociological dimension of the large scale implementation of ENDA SYSPRO's GIE model for reversing urban-rural labour migration.
- The Dekh Gui project is managed by the DELTA group (Groupement d' Intérêt Economique GIE), on a SYSPRO farm, which was abandoned two years earlier because poor irrigation methods applied during rice cultivation left the land too saline for further production. The Dekh Gui farm was completely rehabilitated using SYSPRO's approach, involving composting to improve soil macro-porosity, accompanied by an efficient system of irrigation and drainage, which flushed out salts deposited in the soil.
- The Thiabsabelle project consists of mixed crop agricultural development at the Thiabsabelle refugee camp. The project is funded by an European NGO, which provides financial assistance, while ENDA-SYSPRO provides technical extension services. The Thiabsabelle project is located on one of several islands, forming a braided river system, between Matam and Dagana. The project was set up to reduce the dependence of Mauritanian refugees on the HCR. The 60,000 or so refugees were moved into the camp in 1989, following hostilities between Mauritania and Senegal. Women refugees play a major role in the camp's management and are the principal beneficiaries.

C. Lessons learned

Neither case study featured was initiated as a climate change project. They involved many stakeholders with different motivations. Concerning the Diaoulé and Ndiébel projects, the motivations were:

- Local communities: improve their livelihoods;
- Government: access to modern energy; and
- Cooperation agency: technology transfer and creating a technology market.

The SYSPRO project has the same differentiated motivations:

- Farmers: income generation;
- Technical support organization: technology transfer and creating environment; and
- Government: enhance job creation.

However, one can notice that these projects have the potential for serving as climate change mitigation and adaptation projects. They contributed to sustainable development through their multiplier and accelerator effects.

The Diaoulé and Ndiébel plants are overloaded due to the increase in demand. Many activities generating income through energy supply were undertaken. These experiences served as basis for the rural electrification strategy of the country and contributed to introduce and expand the market of PV equipment and devices. PV maintenance services were also developed. An innovative management system involving the various stakeholders (local community, NGO, government and national electricity agency) was initiated.

The SYSPRO agro-forestry projects serve as a reference for the development of agriculture entrepreneurship. They are in the right line of the new agriculture policy of the government and donors.

The main lessons that can be raised from these experiences are:

- Rural energy or related projects can be introduced as long as the demand exists.
- Some basic rural infrastructures should be set up by the government with the support of the cooperation agency.
- Government and the cooperation agency have to allow facilities and incentives for the development of DREs (credit system, decrease taxes for DRE equipment and for products exports, flexible payment of electricity bills, etc.).
- The role of NGOs is very important for the follow up, the promotion, the capacity building activities.
- For energy projects, maintenance and availability of devices as well as regular power are very crucial.
- For agro-forestry, it is important for farmers to have access to land and water, as well as to the market.

Endnotes

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2 EDRC/ENDA: A new sustainable energy path for African development – Think bigger act faster.

3 UEMOA countries : Benin, Burkina Faso, Cote d'Ivoire, Guinee Bissau, Mali, Niger, Senegal.

4 UNDP, Rapport sur le développement humain, 2002.

5 Decision /CP.8, The Delhi Ministerial Declaration on Climate Change and Sustainable Development.

6 Ref. The potential of solar power for rural development in the Sahel-Youba Sokona Enda-TM.

7 The greater the number of subscribers, the higher the electrification rate and the earlier the rural electrification target would be achieved.

8 IX^{ième} Plan d'Orientation pour le Développement Economique et sococial 1996-2001 published by the Ministry of Finances (Feb. 1997).

Also see ASER's Terms of Reference.

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12 Venema, *et al.*, (1997). A water ressources planning response to climate change in the Senegal River Basin. In *Journal of Environment Management*, 49, 125–155.

13 Refer. Projet de séquestration du carbone dans les systèmes agro-forestiers. (Syspro, juillet 2003) et étude de faisabilité d'une entreprise privée communautaire villageoise de production et d'exportation de fruits et légumes (Syspro, 2001).

6. Country Study: Zimbabwe

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6.1 Introduction

Zimbabwe is an increasingly water-stressed and deforested country. These two features of environmental degradation are intimately linked through agricultural practice.

Zimbabwe experiences high run-off from its central plateau, with river systems draining in all directions. Water resources management is a major priority for government and storage dams and deep wells have been developed in various parts of the country to improve water supply, agricultural productivity and food security. However energy services and energy accessibility play a major role in determining both the availability of water resources and the extent to which water resource development can improve food security.

Rural Zimbabwe can be divided into two regions: the commercial farm area where electricity is generally available and the road networks are well developed; and the communal areas where electricity is being introduced and the road network consists mainly of trunk roads and poor access roads for the communities. The communal areas, however, have been a target for water resources development with major dams having been developed for all provinces. The energy supply systems required for water pumping necessary to realize the agricultural benefit have not been developed. Since modern energy is a prerequisite for irrigation, it becomes a primary factor for rural development. About 155,000 hectares out of 2.4 million hectares of cropland have been exposed to irrigation or are still under irrigation. It is estimated that about 260,000 hectares can be irrigated from the available water resources (Zimbabwe Electricity Supply Authority, Expanded Rural Electrification Programme, report on Enduse Infrastructure Development, 2002).

Rural Zimbabwe remains highly dependent on biomass for energy, exacerbating water stress and food insecurity. Deforestation associated with unmanaged biomass extraction is a direct cause of water scarcity as deforestation encourages run-off and siltation of surface water ways and storage dams. Furthermore, deforestation is causing water tables to drop in many agricultural areas dependent on hydrologic recharge from forested watersheds.

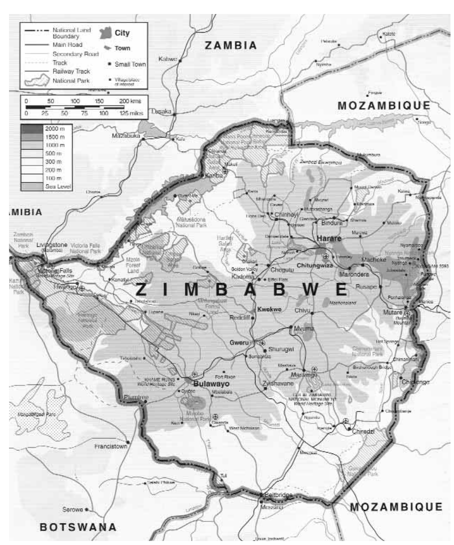
The lack of modern energy services thus exacerbates food insecurity in two fundamental ways: (1) by constraining irrigation from the lack of grid electricity; and (2) and by exacerbating water stress through deforestation, in part caused by biomass dependency.

6.2 Energy-Poverty-Environment Nexus: Rural Energy Situation and Biomass Dependency

Overall biomass contributes 40 per cent of the primary energy in Zimbabwe. Biomass overwhelmingly dominates the rural energy household budget in Zimbabwe.

The extent to which biomass dependency and the rural poverty it implies are responsible for deforestation is debated. Given that 60 per cent of the deforestation rate is attributed to land clearing for agriculture, up to 40 per cent of deforestation can be attributed to fuelwood demand. Estimated levels of deforestation for the period 1990–1995 more than 10 times the corresponding afforestation rates. Arguments are made that fuelwood use is not the primary cause for deforestation since rural families prefer dry trees to green trees for fuelwood. This argument is only true in areas of abundant wood where the option to use dry wood exists. In most areas in Zimbabwe

Figure 6.1 Map of Zimbabwe



the population densities are high and demand for dry wood outstrips supply. This implies that fuelwood plays an important role in deforestation, thus if proper intervention measures that reduce the woodfuel demands are implemented, there should be positive environmental gains. In fact fuelwood collection follows closely behind land clearing for agriculture so it further reduces biomass cover further. As the rural population grows, there is increasing demand for land for agriculture. Given the historical agricultural practices that have reduced productivity of the cleared land, most of the population has to manage with less productive land. Tree cover then becomes more critical to prevention of soil loss and regeneration of abandoned lands. The availability of surface water is closely linked to vegetation cover. In the absence of vegetation cover, run-off increases and surface water systems flood under heavy rains but dry out during the dry season. Household and livestock water supplies are the first to suffer, followed by rainfed crop production.

The fuelwood situation is similar in other southern African countries as shown in Table 6.1. Even though some countries show excess wood resources, the trend towards constrained supply is apparent.

Table 6.1 Wood fuel resource extraction in Southern Africa

	Vegetation cover ('000 hectares)	Deforestation rate ('000 ha/year) (1990–1995)	Afforestation rate ('000 ha/year)
Angola	51,863	237.0	3
Botswana	26,527	70.8	–
Kenya	16,773	3.4	10
Madagascar	23,188	130.0	12
Malawi	3,697	54.6	1
Mozambique	14,028	116.2	4
Namibia	17,970	42.0	–
South Africa	8,181	15.0	63
Sudan	44,353	–	13
Swaziland	120	–	5
Tanzania	33,456	322.6	9
Uganda	5,496	59.2	2
Zambia	28,674	264.4	2
Zimbabwe	8,792	50.0	4

Source: AFREPREN

Rural electrification rates are relatively high by southern African standards.

Table 6.2 Population distribution and energy use in southern Africa

	Population (million) 1999	Rural population (%) 1999	Modern energy consumption ('000 toe) 1998	Electricity consumption per capita (kWh) 1998	Rural electrification levels (%) 1998	No. of rural households connected to electricity 1996
Angola	12.4	66.44	1,610	92	–	–
Botswana	1.6	50.22	1,150	–	8.0	10,714
Malawi	10.8	76.40	–	87	0.32	4,400
Mauritius	1.2	58.86	–	2,556	100.0	117,720
Mozambique	17.3	61.08	490	48	0.7	13,603
Namibia	1.7	69.56	900	–	9.0	9,917
South Africa	42.1	48.35	94,650	4,302	46.0	1,814,904
Swaziland	1.0	73.88	–	–	2.0	1,953
Zambia	9.9	60.48	–	777	1.4	17,499
Zimbabwe	11.9	65.40	–	672	17 0	237,977

Source: AFREPREN

The rural electrification program is progressing at a slower rate than would be sufficient to curb deforestation. The main constraint is financial where US$300 million is required to sustain the program. Cash inflows are much lower than outflows since rates of connection are low. In any case, rural loads are spread out with the result that the transmission and distribution costs cannot be met by a subsidized tariff. Apart from utility constraints the energy users have to invest in end-use capital. In most cases this is higher than connection fees and communities are not able to raise such amounts for the required initial expenditure.

A Rural Electrification Fund has now been formed and is the key agency for grid electrification in rural areas. The fund is headed by a board with members from the utility, the Agricultural and Rural Development Authority, the Ministry of Energy and Power Development, the Zimbabwe Institute of Engineers, the Rural Electrification Authority and Administrators from eight of the nine provinces in the country. The technical team for the Rural Electrification Agency consists of a Chief executive and three Directors, eight Provincial Engineers and 57 District Technicians. Most of the construction work is contracted out to establish a separation from normal utility work. The utility maintains the system. Communities that are able to make a contribution are connected first and grid extension progresses from existing sites to the next nearest site. As the program progresses there will be a much denser network of power lines that will enable households close to the grid to connect. Households beyond a kilometre from the line will most likely be unconnected due to the high fees charged and low projected load. The target for any grid based rural electrification program cannot be full electrification of households but reduced rural poverty to the extent that most communities gain access to electricity. The fund has issued Rural Electrification bonds with a yield of 35 per cent per year and a target of ZWD5 billion (US$5 million at current rates at time of issue). A six per cent levy is also collected on all electricity bills. Up to US$300 million is needed in hard currency to support the program. Ideas have been suggested on how to raise the required currency, including the commitment of export earnings from successful rural electrification projects to debt service and asking export earners to settle electricity bills in foreign currency.

Land degradation is given as the main reason for providing grid electricity to rural communities so they can stop using firewood. The National Conservation Strategy indicates the need to replace wood burning stoves with alternatives, including electricity, because the wood-felling has resulted the degradation of large tracts of land (National Conservation Strategy, Natural Resources Board, 1987). It is, however, appreciated that this long-term objective can only be achieved by the gradual upgrading of rural productive systems. The extension of the grid is only one step in the process and the Zimbabwe Electricity Supply Authority carried out a study to assess the requirements for end-use infrastructure development with assistance from WAPCOS of India in 2001.

This is a long-term goal as the rural poor are not able to pay for grid extension and recurrent electricity bills. Poverty alleviation, on the other hand, tends to dictate that rural communities have access to modern energy such as grid electricity. Government has therefore viewed subsidies as the only option for kick starting access of rural communities to electricity.

Electricity does not generally supplant biofuels directly, but increases livelihood opportunities, agricultural productivity, income-generating opportunities and the ability of rural households to increase their consumption of higher quality and higher efficiency energy sources.

6.3 Poverty and environmental implications of rural energy situation

A. Biomass use

Traditional household biomass energy use produces gases that pollute the air. Indoor air quality is a function of type and quality of fuel used, ventilation provided, cooking appliance used and prevailing weather conditions. Most low-income houses in rural areas have small windows and are usually equipped with low cost appliances if not an open fire. Ninety-nine per cent of rural households use a wood stove, which is in use for six to eight hours per day. Over 90 per cent of the rural population use paraffin fuelled wick lamps for lighting.

The levels of exposure are highest for women and children who spend most of their time in the kitchen.

The World energy Assessment Report, UNDP (2000) indicates that one kg of wood per hour yields the following emissions.

Table 6.3 Emissions from wood use in mg per m³ in a kitchen with a volume of 40m³

	Carbon monoxide	Particles	Benzene	1,3-Butadiene	Formaldehyde
Emitted	150	3.3	0.8	0.15	0.7
Recommended	10	0.1	0.002	0.0003	0.1

Source: UNDP, World Energy Assessment, 2000

The above values are much higher than recommended exposure level limits for health protection. There are other hydrocarbons that are emitted but not listed above, including nitrogen oxides, acrolein, toluene, styrene, benzopyrene and methane, all of which are damaging to health.

Every year in developing countries an estimated two million people die from exposure to stove smoke inside their homes. Women, infants and young children follow the largest proportion of these deaths from poor rural families who lack access to safe water, sanitation and modern household fuels. Thus, poverty and environmental health are inextricably linked and reinforce each other in various ways. Lack of basic infrastructure, unhygienic conditions, inadequate health facilities, and lack of education and awareness exposes the poor to greater risks and makes them more susceptible to disease and infection.

Although studies have shown that Zimbabwe has mini-hydro, crop waste, solar energy and animal waste that could be used to supply clean energy to rural communities, the continued reliance on biomass for primary energy contributes to the degradation of rural ecology. Soil loss is estimated to between 40 to 100 tonnes per year in some areas because tree and other biomass cover has fallen from over 75 per cent in 1964 to below 25 per cent in some areas. This is most visible in the Save River catchment area where the largest inland river is now mostly sand and cannot support irrigation for some of the most viable intensive farming areas in the country (B.M. Campbell *et al.*).

B. Deforestation

Deforestation is closely linked to food and water security. The rate of national population growth rate is well above two per cent while 70 per cent of the population resides in rural areas. Rural to urban migration is high but there is limited employment, hence the level of migration is lower than it would be under normal economic circumstances. One of the factors driving the rural-urban exodus is the high rate of deforestation, 40 per cent of which is estimated to come directly from fuelwood demand. In fact, fuelwood collection follows closely behind land clearing for agriculture. Given that the historical agricultural practices that have reduced productivity of the cleared land, the growing population has to manage with less productive land. Maintaining tree cover is critical to the prevention of soil loss and regeneration of abandoned lands. The availability of surface water is, in turn, closely linked to vegetation cover. In the absence of vegetation cover, run-off increases and surface water systems flood under heavy rains but dry out during the dry season. Household and livestock water demands are not met, and rainfed crop production suffers. Higher precipitation levels are require to raise moisture levels for early crop germination and the impact of reduced precipitation is felt much more than when soil moisture does not fall too low in the dry season.

Table 6.4 shows distances covered by families for water collection during dry years in some areas. The table represents the effect of a drought year, but reflect the low levels of water security in these rural communities. As distances increase, families tend to use the nearest water source without paying much attention to quality. Sanitation and hygiene become critical with low water supplies. The situation deteriorates over time as population increases and access to land diminishes.

Table 6.4 Percentage of households travelling specified distances to fetch water

Distance (km)	% Chiweshe area	% Zviyambe area
0–.5	21	12
.5–1	9	9
1–2	13	15
2–4	16	11
4–8	25	28
8–32	17	26

Source: The Save Study, B.M. Campbell et al

Rural communities have generally been viewed as having no ecological management strategies. This has however been realized not to be the case, since there are ecological management mechanisms that are embedded in the community's culture. Varying from one area to the other, there are specific species of trees that are never to be cut down for whatever purposes. Such trees are usually fruit-providing or have some significance in the history or culture of the concerned community. These trees, usually large trees, have tended to remain even in areas that face serious levels of deforestation. In some cases, trees are normally conserved in particular areas, usually dambos and mountains that are considered sacred. These measures, though they do not have a significant impact due to the high rates of deforestation, have left green patches in highly deforested areas. The measures on their own are now completely inadequate to control critical tree cover loss, hence the high levels of deforestation.

C. Vulnerability

The gravest threats from climate change to the livelihoods of rural poor are the additional stresses it places on agricultural productivity, both in terms of heat stress to crops and the increased incidence of drought. Although agriculture contributes just 19 per cent to the gross domestic product of Zimbabwe, the subsistence and social security of the people is intimately related to subsistence farming and commercial crop production. Over 70 per cent of the people in Zimbabwe are dependent on agriculture for their livelihoods. In other countries in southern Africa, this figure is much higher. Food production from poor communities accounts for the bulk of their total food intake.

Climate change will affect the rainfall and temperature patterns of most countries and the agricultural sector is most vulnerable to these impacts. The Intergovernmental Panel on Climate Change (IPCC), in their Third Assessment Report, indicates that variations in temperature are likely to cause more negative than positive effects on food production in the tropics. Most crops are already near their temperature limits for successful growth, therefore yields would fall with further temperature increases. Irrigation and other high-tech methods can be used to maintain yields on commercial farms but this does nothing to provide for the food security of low-income groups due to their inability to purchase food in formal markets. There is already a large proportion of the poor in developing countries, including Zimbabwe, that are now vulnerable to food shortages and this is bound to increase with climate change impacts.

Adaptation strategies include increasing irrigation for subsistence crop farming and the increase of crop output from artificial shelters (greenhouses and sheds) together with the employment of more energy intensive practices for production and storage of food products.

The other major anticipated impact on rural livelihoods from climate change is increased hydrologic stress. Table 6.5 shows the anticipated climate change impacts on the rainfall—run-off characteristics of the major African river basins; for example, run-off from the Zambezi is expected to decrease by up to 40 per cent. Zimbabwe is on a plateau and run-off is very high during the rainy season. In the absence of dams and reservoirs, very little stored water remains inland by the end of the rainy season. Historically, reservoirs have generally provided three to four year storage, but as population increases and climate change advances - and with it the frequency of low run-off years, reservoirs are becoming less reliable. Deep wells tend to have a more reliable supply pattern with minimal variations in single or repeat droughts.

Table 6.5 Change in rainwater parameters due to climate change

	% change in parameter		
Basin	Precipitation	Evaporation	Run-off
Nile	10	10	0
Niger	10	10	10
Volta	0	4 to -5	0 to -15
Schebeli	-5 to 18	10 to 15	-10 to 40
Zaire	10	10 to 18	10 to 15
Ogooue	-2 to 20	10	-20 to 25
Rufiji	-10 to 10	20	-10 to 10
Zambezi	-10 to -20	10 to 25	-26 to -40
Ruvuma	-10 to 5	25	-30 to -40
Limpopo	-5 to -15	5 to 20	-25 to -35
Orange	-5 to 5	4 to 10	-10 to 10

Source: IPCC – Third Assessment Report

In a drought year or after a season where agricultural output is reduced by extreme weather conditions, the income for poor households is affected seriously and reduced for all income groups. The poor are not able to supplement their own food so they become subject to social welfare provided by government. In most cases this service is not able to provide adequate food because the demand for the service usually exceeds supply. Under a climate change environment, the possibility of extreme weather in a consecutive seasons is high. This means the shortage of food becomes acute in the second season. Another impact of extreme weather is loss of livestock. In most rural households livestock provides not only milk and meat but draft power for crop production and transport as well as manure and social security. Once livestock is lost the availability of food is affected for the current and following seasons. Experience in Zimbabwe has shown that revitalizing food production after a series of droughts requires the provision of seed, fertilizer and tillage in the following seasons for up to five years. Rebuilding the depleted national herd is a long-term activity hence tillage remains a problem for the rural poor even if the following cropping season has normal rains.

If drought conditions persist, the low-income groups tend to suffer more as they are not able to meet the recurrent cost of agricultural inputs after a drought year. The real option for food security for the poor is to secure the growing season; the largest risk is poor rainfall and crop failure and if irrigation is possible this risk is greatly reduced. Several options for financing irrigation schemes for low-income groups have been tried successfully. The table below shows the area under communal irrigation in Zimbabwe for 1972 to 1993.

Table 6.6 Operational communal irrigation in Zimbabwe (hectares)

1972	1983	1993
4,026	4,270	5,859

In the case of flooding or abnormally high rainfall, an alternative is using the winter and autumn production seasons, which still requires irrigation. The difference between the two options is the type of storage, as irrigation after high rainfall tends to rely on seasonal storage whereas irrigation in drought conditions would have to rely on perennial storage or rivers. Alternatively boring deep wells for irrigation is also possible but generally has higher costs.

The critical strategy for reducing climate vulnerabilities is intensified agricultural production for the food security of the rural poor. A list of required inputs to do this; food production, processing and storage is shown in Table 6.7, and includes—critically—the provision of water during the growing season. All of the inputs necessary for this basic climate adaptation strategy require decentralized rural energy, which in Zimbabwe (like its southern Africa neighbours), remains in very short supply.

Table 6.7 Energy use activities in food production

Input supply	Production of;
	Implements
	Chemicals
	Seed
On-farm needs	Tillage
	Transport
	Irrigation
	Crop maintenance
	Harvesting
	Pre-processing
Delivery	Transport
Processing	Grading
	Milling
	Packaging
Storage	Refrigeration
	Construction of facilities
	Loading and off-loading

6.4 Decentralized Renewable Energy

A. Current state of DRE activities

The introduction of renewable energy has, for a long time, been thought of as a solution for the energy problems of rural populations. While, in most cases, renewables have not replaced fuelwood, there are some instances where their introduction has made a significant impact on the lives of the community and the environment. Examples of projects are the Temaruru wind project, the GEF Household PV Pilot Project and the Department of Energy Efficient Stoves Project. Initiatives to disseminate renewable energy have so far focused on providing fringe services like lighting and entertainment without providing solutions to the scarcity of energy for cooking and other revenue-generating activities.

Several decentralized renewable energy (DRE) technologies are currently in use in rural southern Africa. The tables below show a quick analysis of the penetration levels. The tables do not however show the experience to date with the technologies where some technologies may be in use but with very slow market penetration. Such slow movers are PV pumps, solar cookers and biomass electrification. The main barriers are technical, financial and social. Most of the biomass-based electricity generation that is shown is based on sugar mills.

Table 6.8 Technical potential for renewable energy (MW) in Zimbabwe

Technology	Installed capacity (MW)	Technical potential (MW)
Solar PV	0.8	>300
Solar WH	10,000 units	1 million
Mini hydro	1.7	20
Micro hydro	1	15
Biogas	250 units	5,000 units
Wind	*1	MW
Bagasse based cogeneration	45	150
Power generation from sawmill waste	0	250

** author's estimate based on 300 watt pumping machines*

The GEF PV Pilot Project implemented in Zimbabwe was successful as a major awareness campaign but did not achieve the expected penetration levels for the technology to sustain a vibrant solar energy industry. Attempts to disseminate renewables in southern Africa should focus on addressing the major problems faced by rural population. Agriculture is the main economic activity of most rural communities in the region. It stands to reason therefore that if renewable energy is to have an impact on the lives of such communities, it should be targeted at improving or aiding the agricultural activities of the target population. The same goes for other communities that are not close to the grid but could greatly improve their means of production by use of DRE. Targeting such activities would have an effect of economically empowering these communities and allowing them to make better informed choices when it comes to energy issues.

The previous approach where solar PV was used to provide light, entertainment and information is problematic in that it requires a lot of support services to be externally funded in the event of technical problems. Many previously implemented DREs are lying idle as the recipient community was left with no means of generating income to pay for repairs and maintenance. If, on the other hand, DREs are integrated into the means of production, their value and worth will easily be appreciated. An interesting case study links the historical success of low-speed wind mills used for livestock watering and the recent adaptation of modern wind turbines to Zimbabwean conditions.

Figure 6.2 Multi-blade low speed wind pump used in Zimbabwe

The wind mill in Figure 6.2 is installed at a holiday lodge about 100 km east of Harare in Zimbabwe. The windmill supplements water used at the lodge. The owner of the windmill operated four other machines on his farm where they provided water for livestock. It is clear from this case that the machine still performs a useful function since grid electricity is available. Maintenance is done by local staff and spare parts are supplied by the machine manufacturer. The machine in the picture was installed about 1992. It is based on a design by the Intermediate Technology Development Group, ITDG, an NGO of British origin which now operates in Africa, Asia and South America. This organization is not to be confused with IT Power, a private company with historical linkages to ITDG. The machine is a 300 watt multi-blade unit with a six meter rotor diameter. It cuts in at wind speed as low as one meter per second and is usually coupled to a lift pump or a bucket pump. Water from the pump is stored in a reservoir. The typical specifications for this type of machine are shown below.

Table 6.9 Specifications for the IT Windmill used in Zimbabwe

Rotor diameter	6 metres
Number of blades	24
Maximum speed	60 rpm
Average speed	25 rpm
Maximum power	1.3 Kw
Start-up wind speed	1.6–2 m/s
Design wind speed	5.3 m/s
Furling (speed control)	10–12 m/s
Shut-down	12 m/s
Height	9–12 m/s
Mass	1,300 kg
Maximum pumping head	200 m
Water per day at 3.5 m/s wind	15 m^3 (70 m head)

Source: IT Zimbabwe

A local company, Stuart and Lloyds, manufactures windmills under licence from ITDG and installs them for interested buyers. There are other companies building similar machines for the same market. The machines are robust but maintenance requires heavy lifting equipment and some mechanical skills. The

Zimbabwe low-speed windmill sector was developed on the basis of commercial farm livestock watering. Even though most large-scale commercial farms were grid-connected, these wind-driven pumps were developed for irrigation and livestock watering in areas far from the grid. An assessment carried out by World Bank in 1987 found that very old machines were still in service and new installations were still being made, albeit at a slow rate. Most of the windmills had been installed due to constraints on diesel fuel supply. Another factor influencing wind pump installation was found to be availability of skills and equipment for maintenance; large machines were to be avoided in remote locations because the machines are bulky and heavy due to their low-speed, high torque operating requirements. Table 6.10 shows data on some of the windmills surveyed. The author highlights that some of the years are estimates since no records were available. In some cases, the machines were made much earlier than the time of their current installation implying multiple users. The data in the table are old but considering the life span of the machines the table is still a useful indicator of the extent to which this simple technology was an appropriate intervention that increases water and food security for their users.

Table 6.10 Survey of wind pumps (1987)

	Windmill size (Trade No.)						
Period of installation	**6**	**8**	**10**	**12**	**14**	**Total**	**%**
Before 1940	–	–	1	–	–	1	1
1940–1949	–	–	2	3	3	8	7
1950–1959	1	–	21	5	–	27	23
1960–1969	1	4	18	20	2	45	39
1970–1979	3	–	10	6	1	20	17
1980–1987	–	–	2	8	3	13	11
Not placed	–	1	1	–	–	2	2
Totals	5	5	55	42	9	116*	
%	4	4	48	36	8		100

B. Case study: Wind power development in Temaruru and Dumbamwe

The Temaruru wind power project was established to supply electricity to the rural communities of Temaruru and Dumbamwe in Makoni district of Manicaland Province and about 150 km east of Harare. The project provides battery charging and electricity services for the local business centre. The project was established as a demonstration of a community run power project based on locally manufactured technology.

The project area is a typical rural setting in Zimbabwe. The main economic activity of the community is subsistence farming with some cash crop production. Temaruru and Dumbamwe are on the central watershed, latitude 18 degrees south and longitude about 32 degrees east with streams draining east and west. The Ruenya and Save rivers drain eastwards and the Mazowe and Mupfure rivers drain to the west and north west from the project site even though the Mazowe river eventually flows east into Mozambique. The area receives up to 1,000 mm of rain in a normal rain season. Signs of soil erosion are everywhere, primarily due to tree cover loss and overgrazing.

The above picture shows the extent of tree cover loss in the Makoni area. The background shows a granite outcrop with some bushy vegetation surrounding it. Most of the trees are young indigenous varieties that have survived due to current initiatives to curtail tree cutting. Many of the trees in the area are exotic wattle and eucalyptus which are spreading due to extensive agro-forestry along the eastern highlands about 100 km from Makoni district. The picture shows clear signs of overgrazing which is a direct cause for soil loss and increased run-off during the rain season.

Figure 6.3 A view of the typical scenery in the Makoni area where Temaruru is situated

The type of shelter used by the community is a mix of burnt bricks and asbestos roofing and the traditional round hut built out of burnt bricks and grass thatch. Thatching grass, construction poles and other building material normally obtained from natural forests are no longer available. The community now relies on timber purchased from nearby commercial farms.

The environmental importance of the Makoni district is not only for the survival of the local communities but for the preservation of the Save catchment area. The Save River is the largest inland water course in Zimbabwe, covering 42,000 square kilometers and home to about 40 per cent of the human population residing on communal land in Zimbabwe. It is split almost equally between commercial farms and communal lands but the major part of the environmental problem emanates from land-use practices in communal areas. IUCN – The World Conservation Union, commissioned a study to assess the scale of the problem and to identify options for rehabilitation of the catchment area. In consultative workshops held as part of the Catchment Area Rehabilitation Project, the problems identified by the various interest groups were as follows:

- Unfavourable physical and climatic conditions.
- Excessive soil loss and land degradation especially in communal areas.
- Severe deforestation leading to shortage of fuelwood and building timber, especially in the communal areas.
- Deteriorating water quality and quantity.
- Difficulty of harnessing and maintaining adequate water resources.

- High population growth rate causing imbalances between population and available resources, leading to excessive poverty and the unavailability of basic resources.
- Unfavourable land tenure systems.
- Lack of alternatives and appropriate technology.
- Uncoordinated action and activities.

Government Perception

- Problems associated with the management of common property resources and land-use planning.
- Instituting production oriented land tenure systems which are sustainable and backed by appropriate administrative arrangements.
- Making recommendations on absentee farmers, women's land rights and alternative social security for formal employees.

Community Perception.

- Absolute poverty causing them to engage in unsustainable resource use practices such as stream bank cultivation, brick moulding and firing with wood, etc.
- Lack of water and land.
- Lack of alternatives.

Relevance of the project in the community

The objectives of Temaruru project were to support and develop appropriate technology for rural development. The project was supported by Danish funds and the Danish wind industry, which observed that there appeared to be opportunities for wind technology applications in Zimbabwe. The main objective was to define a wind map of Zimbabwe and to develop test schemes at sites showing high potential. The key challenge was to design improved technology for use of the limited resource. The project was later integrated into the rural development program called the District Environmental Action Plan, where capacity building for energy planning was also a component.

The project shows how a technology solution can be developed to fit into rural priorities despite the high transaction cost that arise from the need for market development and extended technical support. The community owns the project but it will be seen later that decisions are still driven from the top.

The environmental and social problems in the recipient community concern food security, supply of clean water and provision of basic social services. The priority for communities in the area concerns poverty reduction and the priority at the national level is rehabilitation of the ecology, which clearly links to global biodiversity conservation objectives.

In this context, the introduction of wind power is obviously not a panacea, however it does demonstrate the indigenous capacity for innovation and the potential for extending the service to critical rural development objectives. The current applications are to do with lighting and refrigeration but there is an array of other applications that could benefit from the project such as water pumping, communication, education and light manufacturing. Supply of clean water has direct relevance to the community problems as it would improve on health and reduce expenditure. Water is a major medium for the transfer of pathogens and clean water eliminates the possibility of infection and outbreaks of stomach related illnesses. The pilot project may be small but the potential for expansion and replication is large. Direct substitution of fuel wood is not ideal for the technology due to the limited available energy. However developing alternative income sources and irrigating woodlots for biofuel production is a real possibility. Poverty reduction through the creation of opportunities for income generation allows people to choose energy sources. With increased incomes, biogas digesters, use of liquid petroleum gas and kerosene all become possible, all of which help conserve the available standing biomass.

Project design and management

The project was built as a test case run by the recipient community to demonstrate the viability of wind-electric machines in Zimbabwe. There are no technical skills for wind power within the community and prior to the project, the community had no knowledge that wind was available and could power lighting and refrigerators. Previously it had been thought that wind speeds were too slow for viable electricity generation in Zimbabwe. The only wind machines that were therefore marketed were the mechanical wind pumps featured earlier. Through a Danish-funded project a wind resource survey was carried out by ZERO, a regional environment organization in Zimbabwe. The project collected data at various selected sites including Rusape, Dumbamwe, Mt Darwin and Chivhu. Only two sites recorded mean wind speeds above 4 ms-.1 Dumbamwe was selected as the project site. Mechanical wind pumps have been built for decades but electric generation from wind was yet to be introduced; this project therefore introduced all dimensions of technology transfer and utilization in a rural setting. The institutional framework had to include the local and global levels for successful operation of the project. The technology had to be developed to suit local conditions and the community had to be able to receive it and manage its operation including the financial aspects of the "new business." Generation of cash incomes was not the main objective, it was rather the delivery of electricity as a service for lighting and refrigeration.

Technology

The technical design team monitored data and then applied longer-term data from the Meteorological office to predict performance over a longer period. This gave an indication of the available wind energy, a factor key to economy of operation of the windmills. The wind turbine was designed to these specific local conditions and built as a joint venture between Scoraig Wind Electric of UK and Powervision of Zimbabwe, creating a new industry manufacturing low speed electric windmills in Zimbabwe. The joint venture is called African Wind Power (AWP). Powervision is jointly owned by Powertronics of Zimbabwe and Innovision of Denmark. Manx Wind Energy and Scoraig Wind Electric provided the engineering design services for the wind project. African Wind Power has been in existence for six years. At present, it manufactures the AWP3.6 1000W wind generator in Harare. Ninety-nine per cent of these machines are exported to South Africa, Mozambique, Europe and the U.S.

A new factory has been set up in Johannesburg to increase production and quality. A new eight Kw machine will be ready for sale in early 2004.

Figure 6.4 Assembling wind charger controllers at Powervision in Harare

Source: Powervision

In a test period the machine produced 392 kWh in four months which was equivalent to 28,000 ampere hours. In comparison this would equate to 19 by 50 watt solar photovoltaic panels. The machine has a cut-in speed of 2 ms-1 and produces the rated 500 watts at 7.5 ms-1 and full power of 750 watts at 11 ms-1.

The Temaruru site consists of four one kilowatt wind turbines. The machines are 3.6 metre diameter, two-rotor windmills with low-speed permanent magnet alternators attached. There is no gearbox attached and the machines produce 12 to 24V direct current. The machines charge batteries which power the loads at night. The battery centre has a 400 ampere hour 48 volt battery. The direct current is changed to alternating current by an electronic inverter supplied by Powertronics. The electricity is supplied to a shop and a clinic. Plans are on hand to provide a battery charging service where community members can purchase and recharge batteries.

Table 6.11 Project cost

Item	Cost (US$)
Site survey	225
Tower	750
PT3600 wind turbine	1,500
Charge controller	250
Transmission cable	250
Battery bank	2,375
3 kW sine wave inverter	2,000
AC distribution and fittings	1,000
Transport	450
Installation	450
Instrumentation	250
Total	9,500

Source: ZERO

Project administration

ZERO served as the community liaison expert. They assisted in developing the grassroots administrative structures and in linking the technology suppliers to the community. ZERO was also the local group responsible for the overall project liaison with other stakeholders especially with monitoring wind regimes at other sites and data collection from the Meteorological Services. They also did market assessment and project monitoring and evaluation.

Management committee

On the local level the day-to-day operation of the project is a responsibility of the Management Committee. This Committee is appointed from the community and constitutes of a Chairman, treasurer, Secretary, and Technical Officer. The objectives of the management committee are to:

- Control day-to-day operation of the scheme.
- Monitor system performance and recommend or initiate improvements.
- Appoint and pay supervisor and clerk.
- Audit finances and ensure loan repayments.
- Make purchases and sign contracts with approval from trustees.

The community has no technical responsibility over the system except to report problems. The technical responsibility remains with the technology supplier even though the community has a right to appoint and pay contractors.

Climate benefits and CDM possibilities

The project has displaced the use of kerosene for lighting and refrigeration at the site. The technologies used with electricity are different from those used with kerosene hence the habits of the energy users have changed, however, estimates of emission reductions can be done by assuming that an isolated diesel genset would supply the same energy as the windmill. Regeneration of standing biomass is not easy to quantitatively link to use of electricity from wind.

The windmills generate about 600 kWh per month. A diesel genset would emit about 640 kg of CO_2 in supplying 600 kWh of electricity and coal based grid electricity.

If a new water pump were to be installed the alternative would have to be grid electricity, diesel pump or a wind pump. In this case the wind pump would displace a fossil fuel. In all cases the greatest benefit to the environment including emission reduction would be the ability of the community to access modern energy and to manage natural resources without the pressure to abuse the biomass reserves.

CDM is an appropriate tool for supporting this type of development. The project is confined to a small geographical location and the emission reductions are measurable. The difficulty is with defining the baseline. This can however be overcome by applying the criteria for small renewable energy projects as recommended by the CDM Executive Board. In the case of the Temaruru project the baseline would be either grid electricity or an isolated diesel genset.

Lessons learned

The Temaruru/Dumbamwe project was not conceived as a climate change project. The project however holds potential for serving as a climate change mitigation project with major rural development advantages. In it's current form the project supplies energy to a few shops and a rural health centre. There is potential to expand the project to include energy supply for income generation projects. The lessons learned in implementing this project serve as a basis for more reliable planning for a potential next phase of the project. The following are major leaders from the project:

- Rural energy projects can be introduced with new types of technology as long as the interaction between community and technology is tailored to suit the available skills.
- The community was involved in project planning and development and is happy to be involved in the operation and management of a project that provides indirect benefits. The shops are private businesses but the community realizes the benefits of electricity and is willing to organize and manage the energy project without direct financial compensation
- The wind machine used in this project was developed as part of the project. The technical team needed a machine to operate at low wind speeds and decided to modify a machine used elsewhere in the world. The team involved local and foreign experts and used local technical skills to construct the machines. The technology works well and is now exported to the U.S. This demonstrates that with correct matching of skills renewable energy technologies do not always have to be imported in whole. Soft technology is a major option for technology transfer and has been the key driver for the Zimbabwe wind power industry.
- Given the success of the wind machines in the current applications and the commitment of the rural community it is possible to expand the project and include water pumping and other projects with potential for income generation. The project dispels the theory of insufficient wind speed that has been given for non-use of wind electric machines in Zimbabwe.

Box 6.1 Zimbabwean wind energy spins at Redhill

Feather Energy has erected a small wind turbine as part of a hybrid wind/PV/genset electricity supply system for a home and an office at the Redhill Mountain Reserve above Simon's Town, South Africa.

The system comprises a one kW wind generator, a one kWp PV array and a five kVA petrol genset supplying a 1,000 Ah 24 V battery and a two kVA sinewave inverter.

The energy demand is roughly 3.5 kWh/day during the week—for the office and domestic needs—and 800 Wh/day over weekends. In addition to lights, the office equipment includes two desktop PC's, a notebook PC, a laser printer, deskjet printer, a scanner, a network hub, a fax

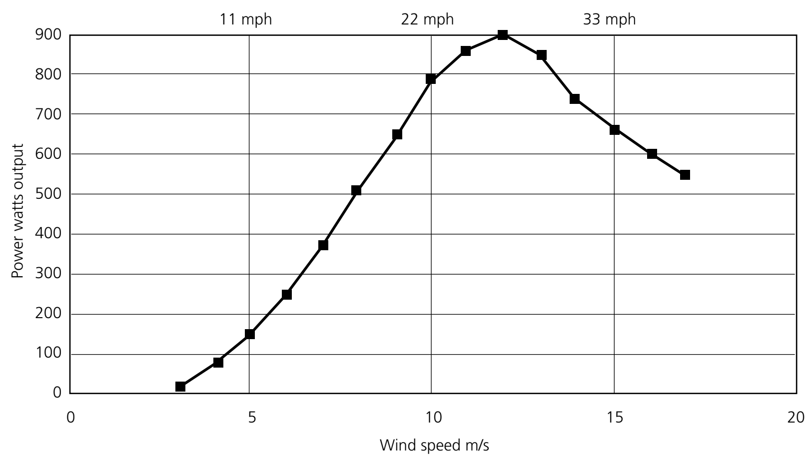
Figure 6.5

machine, a PABX and an answering machine. The domestic loads include a washing machine, small kitchen appliances, a TV and VCR and power tools.

The system has been implemented as a joint initiative between Feather Energy, Powervision, Siemens Solar PDI and MLT Power.

The wind generator is a commercially available product manufactured by Powervision in Harare, Zimbabwe. It is specifically designed for lower wind speed regimes which are typical of the inland areas of southern Africa.

Figure 6.6 Powervision wind turbine power curve



The turbine uses a direct drive permanent magnet alternator, but with skewed windings to eliminate cogging. Power comes from a 3.6 m diameter rotor with three GRP blades. Overspeeding and storm loads are reduced by a gravity furling tail, turning the rotor edge on in winds greater than 18m/sec.

The machine is the direct result of a development project initiated through the Zimbabwe Energy Research Organization (ZERO) in Harare. It has been designed by world leaders in small turbine and machine design including, among others, Geoff Watson (Manx Wind Energy), Hugh Piggott (Scoraig Wind Electric) and Oloff Smyth and Duncan Kerridge at Powervision. The initial objective was to investigate the feasibility of a locally-manufactured simple battery charging wind turbine capable of producing the equivalent power of an array of six 85 Wp PV modules in windspeeds of three m/sec. The principal attraction was that almost all the value added in the production of the machine would be in local currency, hence protecting against the foreign exchange variations that affect imported PV modules.

The turbine has operated to specification and is highly suitable for replication in other countries with a basic engineering industrial base.

The machine at Redhill was installed on a guyed 7.5 m steel tower and was erected over three days by Duncan Kerridge assisted by two inexperienced helpers.

7. Part I – Synthesis

The preceding country studies illustrate various elements of integrated rural development based on decentralized renewable energy projects that simultaneously provide mitigative and adaptive responses to climate change. Although the climate change mitigation potential of DREs are generally well-understood, the country studies demonstrate how DREs also build adaptive capacity to cope with climate change through expanded livelihood opportunities and increased ecological resilience. More specifically, the country studies reveal different aspects of the mitigation-adaptation nexus conceptual framework developed in Section 1.8 and illustrated in Figure 1.12.

The rural electrification case study from Jujuy province in Argentina illustrates that DREs are not always a direct climate adaptation strategy, but can be essential prerequisites for building adaptive capacity. This project succeeded because the implementing agency (EJSEDSA) took a comprehensive development approach that emphasized health services, education and micro-credit provision as essential components of the DRE program, transforming energy services provision into enhanced livelihood security and reduced health risk (linkages 2 and 3 in Figure 1.12).

The two case studies from Bangladesh both illustrate the mitigation-adaptation synergies of bioenergy systems. In the social forestry example, the sustainably managed use of roadside tree plantations for biofuels reduces the deforestation pressure on common-property forests (a mitigation benefit), while simultaneously reducing land degradation—a key climate change vulnerability in Bangladesh. The poultry biofuel case study from Bangladesh is also a profound illustration of the mitigation-adaptation nexus. The shift to poultry-based protein from fish in Bangladesh is in fact a strategy to adapt to declining fish stocks, which are expected to worsen with climate change. Processing the poultry waste as a biofuel produces a beneficial soil conditioner that reduces a key climate change vulnerability (soil degradation), and is simultaneously a greenhouse gas mitigation activity. With respect to mitigation-adaptation nexus conceptual framework (Figure 1.12), the social forestry and the poultry/biofuel case studies illustrate examples of linkages 5 and 11 between bioenergy provision, land resource management, and reduced vulnerability, and can produce a positive synergy (linkage 6) with water resources management by reducing flood and drought vulnerability.

The Brazilian case study highlights a proposed bioenergy project on degraded tracts of land in northwestern Amazonia. Producing biomass feedstock on these lands—vulnerable to further degradation with climate change—produces a mitigation-adaptation synergy by reducing ecosystem vulnerability and enhancing the livelihood dimensions of adaptive capacity by providing employment.

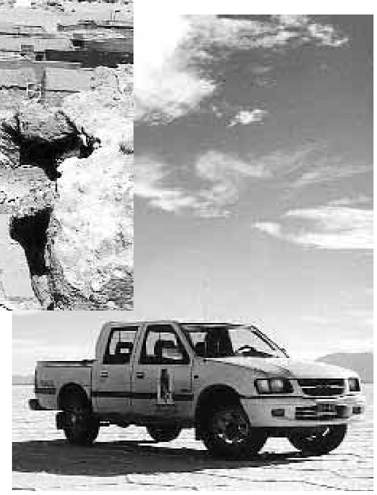
The case studies from Senegal also illustrate fundamental elements of the mitigation-adaptation nexus. Sub-Saharan West Africa, including Senegal, is at extreme risk from climate change which threatens to intensify existing agro-climatological risks, particularly more frequent droughts and hastened desertification. West African countries, which historically have had negligible GHG emissions, are some of the most vulnerable to climate change because of low adaptive capacity related to extreme poverty, exposure to existing climatic stresses and heavy dependence on rain-fed agriculture and biomass energy. Within this context, the adaptation benefits of the rural solar electrification projects at Diaoulé and Ndiébel are very interesting. Many socio-economic benefits associated with electricity provision were observed: improved health services, enhanced livelihood, educational and cultural opportunities (linkages 2 and 3 in Figure 1.12). Additional adaptation benefits relate to the agroecosystem dimensions of energy provision. Electric pumping for cattle watering, for example, enables stall feeding of cattle and eliminates the need for seasonal migration on the part of herders. Cattle dung is available for use as an agricultural fertilizer, improving land resource management and increasing resilience to climate stresses. Furthermore, the livelihood opportunities introduced with electrification have increased household incomes to the point that many households no longer depend on subsistence biomass for cooking thereby alleviating local ecosystem stresses (linkages 4 and 5 in Figure 1.12).

The scenario in Zimbabwe bears a strong similarity to that in Senegal. Zimbabwe is increasingly a water-stressed and deforested country with deforestation exacerbating water resource stresses that may worsen with climate change. In this case study, small-scale windpower eases water resource stress and contributes to climate change adaptation in two ways: (1) by providing energy for water pumping in otherwise energy-deprived areas, and (2) by easing fuelwood consumption in households whose livelihood opportunities have expanded with electrification (linkages 1 and 3 in Figure 1.12). The Zimbabwean case study also illustrates the large potential for technology transfer and adaptation of DRE technology to local conditions—exactly the kind of capacity-building that the Clean Development Mechanism under the Kyoto Protocol intends to support.

Part II of *Seeing the Light* reviews CDM preparedness in each of the five countries and assesses their respective preparedness to seize the opportunities presented by the mitigation-adaptation nexus.

Part II

The Clean Development Mechanism and Decentralized Renewable Energy



8. Introduction to Part II

Realizing the significant potential benefits of decentralized renewable energy (DRE) as a tool for reducing the vulnerability of the rural poor to the anticipated impacts of climate change, in addition to its widely accepted mitigation benefits, requires a rapid and extensive expansion of the implementation of these systems. The cost of establishing DRE systems has declined in recent years due to technological developments and greater experience with these technologies—renewable energy is now "often the least-cost option for providing electricity and other energy forms in rural areas."[1] However, financing the technology transfer and developing the required engineering and rural extension capacity to seize the full potential of DRE still poses enormous challenges for developing countries, particularly for poor communities.

The Clean Development Mechanism (CDM) of the UNFCCC provides unique means through which developing countries can access new sources of direct foreign investment that can be specifically targeted at developing decentralized renewable energy systems. It was established within the Kyoto Protocol to achieve two primary objectives:

1. to provide a market-based mechanism through which governments and private sector entities in developed countries invest in projects that will enable them to reduce global greenhouse gas emissions and meet their Kyoto Protocol targets at a lower cost per tonne compared to domestic reductions; and,
2. to assist developing countries in the achievement of their sustainable development objectives.

Substantial new financial flows into host countries are expected to take place as a result of CDM activities, and the potential for the new funds to be used to finance decentralized renewable energy systems is clear. Renewable energy is one of seven sectors[2] in which projects eligible for CDM registration may take place. A second CDM sector that also has the potential to contribute to the provision of decentralized renewable energy is forestry—specifically afforestation and reforestation activities that may be used to generate the biomass needed for bioenergy projects. Experience to date has demonstrated the potential of the CDM as an instrument for financing renewable energy investments with biomass and wind power projects prominent among the current list of candidate CDM projects.[3] Few developed countries have formally specified their preference for certain types of projects, although large scale hydro power and carbon sink projects remain poorly received (largely for political reasons) by a number of purchasing countries.

The demand, as well as the supply, side of the CDM market is developing rapidly. A number of countries have initiated programs for the acquisition of carbon units, and private companies are also starting to become directly involved in the market. The demand for carbon credits by developed countries in the first commitment period (2008–2012) has been recently estimated by the International Emissions Trading Association (IETA) to be in the range of 300–350 megatonnes of carbon dioxide equivalent ($MTCO_2e$), with the CDM portion falling somewhere in the range of 100 $MTCO_2e$. Judging by the distance of key actors (e.g., Japan, Italy, Spain) from achieving their Kyoto targets at home and, at least in the case of Japan, high projected domestic abatement costs, this number is likely to increase. However, these estimates are uncertain as many developed countries have not yet worked out, or at least released publicly, a clear strategy for the fulfilment of their Kyoto targets. Others have not yet decided on the role the flexible mechanisms will play within their strategy, and have not identified the amount of credits they intend to procure. The demand for credits from CDM projects will depend on the effectiveness of domestic policies and measures, and other trading opportunities available through both joint implementation and international emissions trading.

The CDM Executive Board[4] is actively implementing the prompt start of CDM and it is expected that the registration of CDM projects and the issuance of the first certified emission reductions (CERs) will start as early as 2004.[5] At present, based on where the majority of memoranda of understanding have been signed, it is expected that the majority of CDM projects will take place in South America (Costa Rica and Chile hosting a combined total of 11) and South-East Asia. However, India and China are also emerging as key suppliers. Primary purchasers in the market are currently Japan, the Netherlands, Sweden, Canada, and Finland. The current price range for CERs is between US$3–US$6.5 per tonne CO_2-equivalent. However the transparency in the market is low, as most buyers and sellers are reluctant to provide any information on prices defined in these private purchasing agreements.[6]

As these developments make clear, the CDM is well placed to meet its objective of enabling developed country investors to meet their greenhouse gas (GHG) reduction targets in a cost effective manner. What is less certain is whether the CDM will also be an effective tool for assisting developing countries to achieve their sustainable development objectives, and correspondingly reduce their vulnerability to climate change. The potential for the CDM as a tool for supporting adaptation is rooted in the rationale for the establishment of this market mechanism. As stated in the Kyoto Protocol, CDM projects are to assist Non-Annex I Parties in "achieving sustainable development and contributing to the ultimate objective of the Convention." And as the Delhi Declaration makes clear, sustainable development is increasingly regarded as synonymous with building the necessary adaptive capacity to cope with climate change.

On the surface, the CDM presents an exciting and significant opportunity for developing countries to receive increased financing for the capacity building and technology transfer opportunities that will enable them to achieve some of their sustainable development objectives. By hosting CDM projects, developing countries could potentially guide investment to priority economic areas, reap associated air quality and health benefits, gain access to clean technologies, undertake infrastructure improvements, increase employment, improve land use, support rural development, and potentially reduce dependence on imported fuel—all of which are efforts that support poverty eradication. In the case of unilateral CDM projects, host countries may also gain revenues from the sale of certified emission reduction credits. The benefits of locally targeted initiatives coupled with potentially increased foreign investment dollars make many countries eager to host CDM projects.

For example, several developing countries—mainly in Africa—have reformed their energy sector, a process that has included a re-orientation of national energy policy to include poverty alleviation in some cases. Rural electrification agencies have been mandated to establish decentralized renewable energy systems for supplying electricity and to promote rural livelihood opportunities. These reforms constitute a great opportunity for CDM investment and mitigation-adaptation synergies.

The Designated National Authority (DNA) for the CDM in each developing country has a critical role to play in ensuring that the potential mitigation and adaptation benefits of this mechanism are realized. The purpose of a country's DNA is two-fold: to regulate and approve projects that take place within their borders; and to promote business opportunities to the international CDM community. DNAs are responsible for the evaluation and approval process that assesses a project's contribution to the sustainable development objectives of the host country. Because an official definition of "sustainable development" was not formally included in the Kyoto Protocol it is the prerogative of each DNA to create its own set of sustainable development criteria or guidelines for CDM projects based on local priorities and needs.[7] Host countries may consider a number of criteria including:

- *Social* – does the project contribute to poverty alleviation and equity concerns?;
- *Economic* – does the project include financial returns to local entities? Will the initiative involve transfer of appropriate technology to local communities?; and
- *Environmental* – does the project have co-benefits beyond the reduction of GHGs, such as positive impacts on air quality, health and water quality?

The ability of a country's DNA to ensure that CDM projects contribute to meeting the sustainable development objectives of their country will be dependent on their technical and institutional capacity to: review, approve, develop and promote CDM projects in a systematic manner; assess and remove barriers to implementation; and market project opportunities effectively. Donor countries and multilateral institutions have been actively engaged in assisting developing countries to build this capacity with funding often provided to assist countries in the creation of national authority offices (including input into development of sustainable development guidelines), exploration of market opportunities and development of pre-feasibility studies. As seen in Box 8.1, the majority of DNAs have been established in Latin America and Asia. A well organized, clear and efficient process of approval and facilitation of CDM initiatives stands to influence the quality and number of projects that take place in a given country.

Box 8.1 Designated national authority status

As of February 2004, 41 countries have completed the process of establishing a national authority office, and are now eligible to host CDM projects. The distribution of offices is as follows:

Latin America and Caribbean: 17

Eastern Europe: 4

Africa: 5

Middle East: 5

Asia: 9

Oceania: 1

Other elements of the CDM and its project cycle are critical to facilitating the establishment of DRE projects, including provisions for the establishment of small-scale projects and the development of carbon sinks through afforestation and reforestation practices. Small-scale projects that reduce emissions are known to have greater sustainable development benefits for local communities. However, the transaction costs associated with these projects is considerably higher than for their large scale counterparts. In an attempt to promote these types of projects and their local benefits, guidelines for small projects were implemented by the CDM Executive Board in 2003. These simplified rules apply in three types of initiatives:

1. Renewable energy project activities with a maximum capacity of 15MW.
2. Energy efficiency projects that reduce consumption by up to 15 GWh per year.
3. Projects that reduce emissions from sources of less than 15Kt of CO_2 per year.

Projects falling under one of these three categories are eligible for several benefits that reduce the transaction costs and approval time. Proponents may use a simplified Project Design Document (PDD – the official documentation filed with the Executive Board on the project). Standardized baseline analysis and simplified monitoring methodologies are two other benefits to this track, as well as options to bundle small projects together. Finally, validation, verification and issuance of CERs can be done by a single external accreditor. Small-scale CDM projects are a critical avenue through which developing countries may gain the funding required to support the development of decentralized renewable energy systems. However, in early 2004, of the approximately 70 CDM projects under development, only eight fell within the small-scale category.

CDM investments in carbon sinks also have a critical potential to support bioenergy-based DRE systems. CDM financing can only be used to support afforestation and reforestation activities. Within the international negotiations, agreement on the regulations that will guide sinks' activities only occurred in December 2003 at COP-9. A key question has long been how to allocate responsibility to ensure that the carbon reductions embedded in a sink are accounted for should the carbon be re-released into the atmosphere (i.e., through fire, etc.). The question focuses on whether the project developer, the host country or the owner of the CERs be responsible in such cases. This question was largely addressed at COP-9 by the establishment of credits of limited duration.[8]

Regulations for small-scale sinks projects were also addressed at COP-9. It was agreed that fast-track status is applicable to projects that result in either; net anthropogenic sequestration of less than eight kilotonnes of carbon dioxide per year; and are developed or implemented by low-income communities or individuals. Further clarification of these will be continued at COP-10.

The basis for achieving mitigation and adaptation benefits through the CDM, and specifically through DRE projects, has been laid through the provisions for sustainable development criteria to assess projects, the facilitation of small-scale CDM projects, and the opportunities associated with sinks projects.

Whether this potential can be realized is questionable, particularly in light of the market based nature of the CDM, which places it in competition with other GHG reduction opportunities, and the need for considerable capacity within developing countries to facilitate and host these types of projects. Assessing the potential of the CDM to provide both adaptation and mitigation benefits address several key questions:

- Are CDM investments being made, or can they be made, in a manner that will support the achievement of adaptation and mitigation benefits of DRE?
- Do the developing countries that will host CDM projects have the capacity to ensure that these new investments provide mitigation and adaptation benefits, particularly in relation to decentralized renewable energy projects?
- What actions may be taken to more fully realize the dual potential of DRE projects undertaken through CDM investments?

To answer these questions, we review the CDM experience to date in Argentina, Brazil, Bangladesh, Senegal and Zimbabwe. We examine the existing capacity to manage DRE projects through the CDM, and provide several recommendations for enhancing this capacity—particularly with respect to realizing mitigation-adaptation synergies.

Endnotes

1 World Bank. http://lnweb18.worldbank.org/ESSD/envext.nsf/46ByDocName/KeyThemesMitigation. Accessed January 2004.

2 CDM Projects are eligible for registration if they began after January 1, 2000, and may fall into the following sectors: renewable energy; end-use energy efficiency improvements; supply-side energy efficiency improvements; fuel switching; agriculture (reduction of methane and nitrogen oxide emissions); industrial processes; and sinks projects (afforestation and reforestation only).

3 See for example: http://cdm.unfccc.int/methodologies/process?cases=B (last accessed February 27, 2004).

4 The CDM is supervised and guided by an Executive Board comprised of ten members: one representative from each of the five official UN regions (Africa, Asia, Latin America and the Caribbean, Central and Eastern Europe, and OECD), one from the small island developing states, and two each from Annex 1 and non-Annex 1 parties. The EB holds regular meetings to provide guidance to parties and project proponents on development of methodologies and baselines, and to continue to establish the procedures under which the CDM will function. A separate subsection of the Executive Board was created to deal specifically with rules and modalities on project methodologies, the "Methodologies Panel." (UNEP, Introduction to the Clean Development Mechanism, (no date), http://www.uneprisoe.org/CDMCapacityDev/).

5 Langrock, Thomas and Wolfgang Sterk, "Linking CDM & JI with EU Emission Allowance Trading," Institute for European Environmental Policy, Jan 2004.

6 IETA, "Annex I Parties' Current and Potential CER Demand," Point Carbon, October 2003, at http://www.ieta.org February 24, 2004.

7 Figueres, Christiana (ed.), Establishing National Authorities for the CDM: A Guide for Developing Countries, IISD, 2002.

8 At COP-9, parties came to the following solution: CERs created through sinks projects are to be valid for a limited duration. Furthermore, two types of credits were distinguished. tCERs (temporary CERs) are valid for only one commitment period (e.g., 2008-2012), while lCERs (long-term CERs) are valid for the project's full crediting period (in the case of sinks, 30 years, or 20 years with the option to renew up to two times to a total of 60 years). Both types of credits may not be banked, and must be replaced by another credit (i.e., AAUs, ERUs or CERs) before they expire (Pew Center Summary of Ninth Session of the UNFCCC, December 2003 at http://www.pewclimate.org/what_s_being_done/in_the_world/cop_9_milan.cfm).

9. Country Study: Argentina

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As shown in most of the studies related to the issue,[1] it would appear that Argentina would not be among the most attractive host countries (compared with China, India or Russia, for instance), for a large amount of emission reduction certificates although it does have interesting opportunities in energy demand, industry and transport sectors. Carbon sinks should be considered as still "under study" because there is a lot of methodological controversy about them nationally and internationally, even though Argentina's potential in this subject is quite large.

Regarding the structural transformation of Argentina's energy system, the development of additional DRE projects might be disadvantaged since the State—as a relevant investor—has delegated to market forces the greatest responsibility for energy investments. Actual expansion of isolated rural electricity capacity relies on government subsidies provided by specific national or provincial funds (FEDEI) or external financing from the Global Environment Fund or World Bank (the old PAEPRA or the newer PERMER).

A. Greenhouse gas mitigation opportunities

DRE could be an interesting option for providing energy and particularly electricity in rural areas. Currently, DRE represents only a small percentage of the power capacity; the penetration of additional DRE will lower the share of diesel electricity generation and provide cleaner and sustainable electricity. DRE may also displace fuels or firewood burning in more isolated energy consumers who are not yet electrified.

In this context, the CDM could be an excellent tool for overcoming financing difficulties by providing funds for specific DRE developments.

Following the IPCC methodology for GHG mitigation studies within the UNFCCC framework, the Argentine government carried out a Study on Climate Change in Argentina[2] with the support of the UNDP and the GEF. The 1997 inventory served as a starting point for a series of mitigation studies complementing the GHG Global Project, including mitigation projections and options within the energy, agricultural, industrial, forestry, and waste treatment sectors. Unfortunately, there was not a chapter or section related to rural energy.

The second National Strategy Study (NSS) was made in December 2002,[3] and its results will be an input to the second national communication to the UNFCCC. The main purpose of the study was to provide the Argentine authorities with the necessary platform and tools to develop their own projects and to gather a more thorough knowledge of the existing opportunities for GHG reduction through the mechanisms established by the Kyoto Protocol. The study focused on the following: 1) determining the corresponding emission reduction marginal cost curves in selected sectors; 2) determining the corresponding marginal cost curves of afforestation project implementation; and 3) identifying a project portfolio to be implemented under the CDM.

Some data from the study, showing the relative importance of the different potential of projects to the CDM, are presented in Table 9.1 in order to address the projects' relative attractiveness for this particular mechanism.

To begin with, the incorporation of projects like PERMER in the CDM has already been studied.[4, 5] From the results of these studies, it is estimated that a 50 Wp system could replace the use of kerosene for lighting purposes in rural areas, from 0.5 to 0.7 litres per day per household. Hence, each system could displace some 394 Kg of CO_2 per year. If a total of 65,000 systems of 50 Wp is considered, some 2,561 tonnes of CO_2 would be displaced per year.[6] Even this does not look like a large contribution, in terms of its attractiveness for potential investors, it fits in the CDM guidelines and becomes more attractive if local quality of life improvements are considered.

A concern however is that with GEF financing, project additionality might be difficult to prove, and transaction costs might be an additional barrier. Finally, the sale of CER's emission is judged not very relevant unless its price increases substantially.

If other factors were weighed (sustainable development, social integration, educational and health services improvement, electricity service provision or improvement of rural life quality), this kind of project might be very attractive. As shown in previous sections there is, unambiguously, a necessity of additional rural energy services in the country. If additional funding from CDM can be gathered, then decentralized renewable energy can satisfy these other factors.

Taking a cost effectiveness view, the second NSS shows some interesting possibilities as well as the significance of the potential forestry options. The forestry options are not included because they will require clarification of the CDM rules.

Table 9.1 Most attractive mitigation options

Sector	Alternative	Tonnes CO_2 year
Demand	Street light	317,023
Industry	Co-generation	745,197
Industry	Efficiency	312,116
Demand	Food preservation	1,476,426
Transport	LPG	1,172,990
Waste	Southern coastline 75%	2,461,570
Waste	North III 75%	1,242,104
Demand	Household light	557,855
Demand	Commercial light	977,703
Transport	Biodiesel	1,263,736

Source: World Bank NSS, November 2002

Note: ranked by lower mitigation costs

The aggregate analysis includes four activities on the demand side, two industrial options, two options from the transport sector and two sanitary landfills. The results reaffirm the conclusions of previous studies that show that the best and largest GHG mitigation opportunities in Argentina are not associated with the energy sector.

The project portfolio obtained in the study identifies eligible projects that are tempting for investors and subject to the approval of federal authorities. This analysis should be complemented with the federal government's selection criterion and with the priorities in accordance with the development objectives.

B. Involvement with Activities Implemented Jointly and/or CDM activities[7]

The Argentine experience with Activities Implemented Jointly (AIJ), the predecessor instrument to the CDM, as well as the CDM itself, shows a wide range of results. The CAPEX Combined Cycle[8] – Energy Efficiency Generation Project, which would not likely qualify for the CDM (the Secretary of Energy foresees a 77 per cent participation of this electricity generation technology in the newly installed capacity, expected for the 2001–2010 period). The CACBI project (Canada-Argentina Capacity Building Initiative[9]) however, commits itself to address both Argentina's sustainable development priorities and climate change objectives and is more appropriate for the CDM.

This latter project has a component of capacity building (government, private sector including industry, and NGO stakeholders) together with a technology transfer demonstration, which is intended to convey a practical, "hands-on" experience in developing, implementing, verifying and certifying a CDM project. CACBI's core activities include workshops, training sessions, issue-focused seminars and other technical assistance.

Other project proposals relate to collecting landfill gases for electricity generation and involving the CEAMSE,[10] which is responsible for municipal solid waste disposal in the Buenos Aires Metropolitan Area, are outlined below:[11]

- the proposed use of fuel cell technology for the management of municipal solid waste collection for the productive use of landfill gas in the Gran Buenos Aires area, in association with Conestoga-Rovers of Canada. This project is included within the context of Canadian Government aid and is also funded by CIDA. As with the CACBI project, this project has a capacity building component; and
- the installation by CEAMSE of a system of wells, pipes, blowers, and flares to recover and burn landfill gas from landfills that it currently owns or will own in association with Pacific Energy Systems, Inc. (USA).

Another five CDM potential pre-feasibility projects were detected in Gobierno de la República Argentina–Banco Mundial, 2002 *op. cit*, and are listed in the Annex 9.2b) below the AIJ projects.

It is clear that Argentina is less advanced in the implementation of AIJ/CDM projects compared with neighbours in South America. The CDM office has its own staff and budgeting limitations, but its attitude has always been positive, an example of this is the permanent call for participation to the local experts and actors. Perhaps there have not been enough promotion and information activities all over the country, and project managers are still unaware of CDM possibilities. Other perceived difficulties are the complexities and high transaction costs of the mechanism.

C. Climate change institutions for mitigation and adaptation: capacity and capabilities

Brief survey of national CDM authorities

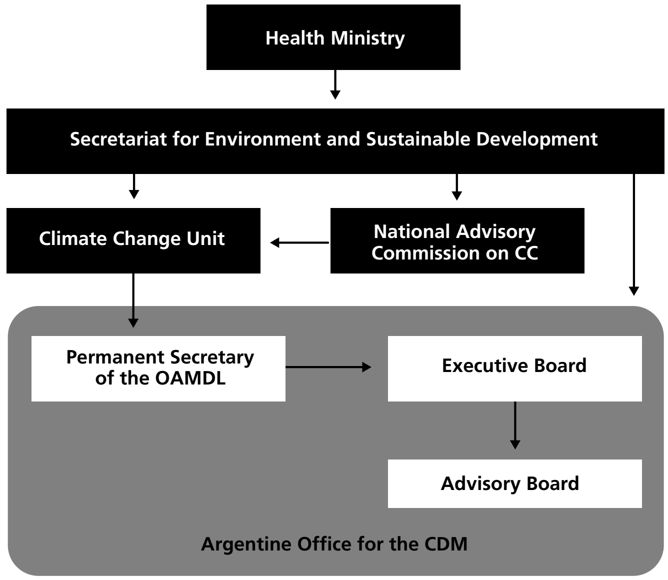
Argentina has historically shown a meaningful and proactive participation in climate change subjects, not only in the framework of the UNFCCC, but also in Kyoto Protocol-related issues. The Secretary of Environment and Sustainable Development has recently expressed as a main priority, the establishment of a National Climate Change Mitigation Strategy. This strategy is to be a key tool in the forthcoming environmental policy, and calls for participation by all sectors of society. There are also demands for putting the secretary at a higher bureaucratic level (currently it is a Secretariat under the Health Ministry).

In regards to Kyoto Protocol implementation, the Argentine Office for Joint Implementation (OAIC) was created by presidential Decree N° 822 in 1998, and was funded by the Argentine Government. In October 2001, the OAIC was transformed in the Argentine Office for the CDM (OAMDL) becoming the Designated National Authority (DNA) for CDM.

The OAMDL was provided with specific normative, modalities and procedures[12] not only to define its missions, functions and composition, but also for the application and approval of CDM projects; it functions as a division of the Secretary of Environmental and Sustainable Development of the Ministry of Health, and is physically housed there.

The Argentine office for the CDM has recently been restructured (see Figure 9.1) and it is not actually receiving applications from project developers, because the proceedings for the process are currently being developed and reviewed. The CDM office is currently encouraging small-scale projects. A local DRE project would fit exactly in this aim. This authority is also working on a list of methodologies in order to simplify the evaluation of additionality, the setting of baselines and monitoring activities.

Figure 9.1 Argentina's CDM organization chart



Source: http://www.medioambiente.gov.ar/cambio_climatico/oamdl/organizacion/default.htm

The core group of the office—Permanent Secretary (*Secretaría Permanente*) and Executive Board (*Comité Ejecutivo*)—are composed exclusively of representatives of the public sector. There is an advisory board (*Comité Asesor*) with representatives from climate change-related NGO's, academia and the private sector. The board has two coordinators, one designated by the Secretary of Environmental and Sustainable Development, and the other elected by the members and belonging to civil society. The OAMDL has regulatory and promotional functions related to CDM and is also involved in evaluation and project approval processes. The funding for OAMDL is provided exclusively by National Government.[13]

The Advisory Board assists the Executive Board in all scientific and technical issues, while the Secretary of the Environment and Sustainable Development is also the president of the Executive Board of the OAMDL, and it settles the number of members of the Advisory Board and designates them at request of the Executive Board proposal. The coordinator of the Climate Change Unit designs the technical team of the Permanent Secretary of the OAMDL.

The Climate Change Unit has the following exclusive policy design functions:

- elaborating and proposing guidelines to the Secretary of Environmental and Sustainable Development; and
- defining strategies and guidelines for the mitigation activities by sector, in line with the National Sustainable Development Policy.

Finally, there is a National Advisory Commission on Climate Change, which assists the Climate Change Unit. It is integrated with representatives of climate change-related NGO's, Academic and Private Sector (sound academics from universities, scientists, professionals, etc.), and representatives of the National[14] and Provincial Governments. The Climate Change Unit has expressed its interest in joining the Advisor Board to this National Commission.[15]

Level of consistency with national policies

The CDM office is taking its firsts steps working on points like sustainability criteria and discussing baselines methodologies under approval in the official UNFCCC. Since it is actively encouraging small-scale projects, considered easier to implement compared with ordinary ones, a well-formulated DRE project would be very well received.

The level of consistency with national polices can not be judged until a real project comes to light. The Economy Ministry is responsible for national development policy, and the Energy Secretariat is in charge of rural energy and electrification. A poverty reduction policy might be considered as a transversal task involving these entities, but lead by Argentina's President. The government has only been newly elected and the consistency and coordination among polices is a major challenge.

The CDM office is currently working on the identification of sustainability indicators, but the definition of the contribution that projects make to sustainability depends on the decision of the host nation. Host nations are in charge of guaranteeing that projects that do not contribute to sustainability do not qualify for the CDM. For Argentina, even a draft of sustainable development criteria is not foreseen because of the lack of institutional continuity and little project experience.

Moreover, it is difficult to find consistency between Argentina's development priorities and the policy related to climate change and the CDM or, more generally, with the environment. Bouille and Girardin[16] express two facts when describing the lack of coherence and domestic support of the proposal to establish a voluntary greenhouse gas emission target for 2008 to 2012. There are currently no sectoral programs owing to the fact that the government's development priorities and policies have never been explicitly and systematically defined in strategic plans and planning processes. Consequently, there are few if any identifiable links between climate protection and sustainable development. Furthermore, within the context of a prolonged economic crisis, the progressive weakening of state institutions aggravated this situation, particularly among institutions dedicated to environmental matters.

Climate change adaptation activities[17]

In relation to adaptation to climate change, the country is not involved in an official and explicit long-term adaptation or mitigation process or activities. Some isolated measures against climate variability can be found mainly at meteorological entities or within the agriculture sector, but are not linked with a climate change threat. There is, generally, a lack of financial and human resources along with academic and scientific dedication to the subject.

On the other hand, in matters relating to adaptation, Argentina's Foreign Affairs, International Commerce and Culture Ministry is worth mentioning. This official body has a long and solid experience in climate change at the international negotiation level. Several officials have been involved in UNFCCC functions representing Latin America and setting the Latin America position on priorities. However, this authority doesn't have a central role in the CDM dynamic.[18]

The provincial and local governments are primarily focused on local pollution. There is an Advisory Board (COFEMA *Consejo Federal del Medio Ambiente*) that consists of one environmental authority from each province, which provides an accurate basin for interaction within the country.

D. Assessment of ability of CDM to support mitigation and adaptation through DRE

In conclusion, it is desirable that the institutions and professionals involved in mitigation and adaptation studies, as well as GHG inventories, take a participating role in CDM implementation at a national and regional level.

The Secretary of Energy has highly-qualified professionals with experience in rural energy national programs and have invaluable contacts with people in remote jurisdictions. They should be involved in studies regarding the viability of DRE programs.

More promotional activities related to the local and global benefits of CDM must be carried on at the provincial level, and they should be done by climate change or CDM experts together with local officials. This will also allow a positive reception from the local population because, as experience shows, local officials need to be kept informed about what projects are being contemplated and their associated benefits and the risks. This would also help to inform local project managers of CDM possibilities.

The CDM office is encouraging small-scale projects because of their ease of implementation. Given this, degree of preparedness, a local DRE project would fit well with its expectations, and is a simple first experience.

According to Bouille and Girardin, "the complexity and dynamism of the UNFCCC negotiation process makes it difficult for sectors like academia to systematically follow and monitor the negotiations, as it does not have the financial support needed. The result is that the academic sector's relationship to this process is intermittent, which blocks the possibility of greater participation in the process."[19] It could, therefore, be useful to establish a permanent communication between the actors gather at the CDM office (climate change-related NGO's, academics, university professionals, scientists, managers and environmental professionals from energy firms and CDM potential sectors, etc.) in order to keep them informed, actualized and committed to the objectives of the office.

When addressing the institutional needs of the country or the development of appropriate CDM capacity and opportunities some conclusions should be pointed out:

- The consolidation of the CDM Office presupposes the observance of several steps, among them: a clear definition of the mission and objectives, official status, federal legal framework, alignment with federal sustainable development policies, development of priorities, consolidation of a wide participation of public and private agents, resource guarantees, clear coordination with other government sectors that complement CDM objectives (energy, agriculture, industry, transport, forestry, housing, etc.), and a definition of the technical staff and its required profiles.
- The CDM office requires a clear and solid institutional link with other state bodies in areas related to climate change, biodiversity, Montreal Protocol and private institutions or NGOs in the environmental field and specific production sectors.
- For their validation and verification, all projects must be submitted in the format of a project design document, which in the case of Argentina, is currently under preparation. The projects must also respond to federal sustainability criteria. The guides for the submission of projects must be consistent and clear so that the project developers are not subject to confusion and changes of format for the submission of their projects.
- One of the most serious challenges to successfully identifying and implementing CDM projects is the determining which sectors will play an active role and how they will be encouraged to use the CDM.
- The State—through the government—has a clear function to approve projects and confirm that they contribute to sustainable development, and to cooperate with the private sector so that the market may act as an efficient mechanism for implementation.
- Finally, one of the key promotional issues is information sharing with the business community and non-government organizations, and the provision to potential investors of access to the following: the institutions or consultants that provide technical assistance towards the identification, formulation, design and development of CDM projects; institutions or agencies acting as "brokers" or intermediaries between buyers and sellers; accredited operating entities providing validation, verification and certification services; and data on real or virtual markets where potential buyers and sellers may obtain information on prices and conditions. This implies the development of an information system to make known the evolution of the mechanism and the opportunities it offers.

Bouille and Girardin also recommend that ultimately, "Any action also needs to fit within the framework of long-term state policies. Otherwise a change in administration will yield policy changes that do not provide continuity. Argentina's policy definition in general, including climate change, is made in the context of the short-term politics of the moment and is not linked to sustainable development policies."[20] CDM implementation should include, in the first place, an adequate articulation within the nation's long-term social, economic and environmental objectives and policies.[21] DRE, as a way of providing sustainable energy, needs to be articulated within long-term energy policies, which must in turn fit within the national sustainable development policy.

Endnotes

1 "The future opportunities for non-Annex II countries – like Argentina – have been discussed in meetings and in documents on the flexibility mechanisms and on the future markets for trading GHG emissions credits. Although countries could benefit by taking advantage of the Kyoto mechanisms and taking "early action" on climate change, they evidently differ in their capacity to influence emissions reductions markets and thus benefit from the mechanisms" Bouille, D. and Girardin, O. (2002), p. 148. WRI. "Building on the Kyoto Protocol. Options for protecting the climate." Chapter 6: Learning from the Argentine Voluntary Commitment. USA.

"In this sense the opening of a global market to trade emissions credits would create opportunities for the large suppliers (e.g., China, India, and Economies in Transition). Together these countries could supply more than 80 per cent of the demand. The remaining 20 per cent could be distributed among 130 other countries, including Brazil, Mexico, Indonesia, Malaysia and Korea. It is also undeniable that "hot air" will serve to depress price levels, and consequently reduce the range of viable mitigation options for developing countries like Argentina" See also MIT, (1997) Emissions Predictions and Policy Analysis Model. Cambridge: Center for Global Change Cience and Gobierno de la Republica Argentina – Gobierno de Canada – Banco Mundial, (1999), Estudio sobre los Mecanismos de Flexibilización en el Contexto de la Convención Marco de las Naciones Unidas sobre Cambio Climático (CMNUCC) y el Protocolo de Kioto.

2 Programa de las Naciones Unidas para el Desarrollo/Secretaría de Ciencia y Tecnología. Inventario de Gases de Efecto Invernadero (1997), Mitigación de Gases de Efecto Invernadero. Evaluación de la Vulnerabilidad de la Costa Argentina al ascenso del nivel del mar. Vulnerabilidad de los oasis comprendidos entre 29° y 36° S ante condiciones más secas en los Andes altos. Vulnerabilidad y mitigación relacionada con el impacto del cambio global sobre la producción agrícola. Proyecto ARG/95/G31. PNUD/SECYT. Buenos Aires, diciembre.

3 The First National Strategy Study was elaborated in 1998 and publicated in Gobierno de la Republica Argentina – Gobierno de Canada – Banco Mundial, (1999), *op. cit*.

4 Kaufman, S. "Towards a Streamlined CDM Process for Solar Home Systems – Case Studies in Selected Countries: Argentina" November 2000/ECN-C-00-110a

5 Ybema, J.R. *et al*. "Towards a Streamlined CDM Process for Solar Home Systems – Emission reductions from implemented systems and development of standarized baselines " November 2000 – ECN-C-00-109.

6 Gobierno de la Republica Argentina – Banco Mundial (2002) Estudio Estratégico Nacional para Hacer Uso de los Mecanismos Flexibles del Protocolo de Kioto, Informe Final, Buenos Aires, diciembre.

7 All the information we could compile related to AIJ/CDM projects presented in an official way in Argentina is included in this section. There were few lessons learned for those activities due to the fact that there were few projects presented. Nevertheless the main doubts related to the mechanism are the mechanisms' current and future status, modalities and conditions for prices, demand and supply. We remark that there is not an Argentine CDM project submitted yet.

8 Listed with number 2 in Annex 9.2a).

9 Managed by The Delphi Group and Joaquín Ledesma & Asociados and funded by the Canadian International Development Agency (CIDA). http://www.delphi.ca/cacbi/

10 Metropolitan Area Ecologic Coordination State Society (Coordinación Ecológica Área Metropolitana Sociedad del Estado).

11 The case of landfill gas is specially mentioned, because it addresses an urgent necessity of Buenos Aires city, local pollution due to domestic disposals recollection.

12 See ANNEX I for the full list of regulations up to May 2003.

13 The Permanent Secretary functions are:

- Identification of sectorial areas for implementing mitigation activities.
- Identification and analysis of mitigation options in the sectors applying to CDM.
- Formulation of guidelines for submitting CDM projects.
- Setting methodologies and proceedings for the identification, formulation and evaluation of CDM projects, design of proceedings for its approbation.
- Development of preliminary activities for project evaluation.
- Development of promotional activities for the commercialization of CDM projects at the national and international level.
- Supervision of the design of monitoring and verification activities.

- Identification of financial sources for CDM projects.

The Executive Committee is in charge of approving the decisions of the Permanent Secretary in order that they are implemented.

14 At the National level there have been invited to join this Commission: the Secretariats for: Energy; Transport; Agricultural, Livestock, Fishery and Food; Industry; Commerce and International Economics Affaires; Foreign Affaires and Science, Technology and Productive Innovation.

15 Expressed by the Climate Change Unit Coordinator during the Advisory Committee to the OAMDL first meeting, held on May 12, 2003.

16 Bouille, D. and Girardin, O. (2002), p. 148. WRI. "Building on the Kyoto Protocol. Options for protecting the climate." Chapter 6: Learning from the Argentine Voluntary Commitment. USA.

17 The vulnerability in Argentina has not yet been related to energy sector issues.

18 The participation in most of the mentioned official publications reflects this fact.

19 Bouille and Girardin (2002), p. 147, *op. cit*.

20 Bouille, D. and Girardin, O. (2002), p. 152, *op. cit*.

21 Gobierno de la Republica Argentina - Banco Mundial (2002), *op.cit*.

Annex 9.1 The Argentine legal framework with reference to climate change

Federal Laws	
24295	07/12/1993 United Nations Framework Convention on Climate Change.
25438	20/06/2001 Approval of Kyoto Protocol of the United Nations Framework Convention on Climate Change.
Federal Decrees	
2156/91	P.E.N. 15/10/1991 National Commission on for the Terrestrial Climate System Global Change.
822/98	P.E.N. 16/07/1998 Creation of the Argentine Office on Joint Implementation.
377/99	P.E.N. 16/04/1999 Commission on GHG emissions.
481/00	P.E.N. 13/06/2000 Greenhouse Effect – Memorandum of Understanding.
2213/02	P.E.N. 04/11/2002 UNFCCC. Designation of the Secretariat for Environment and Sustainable Development as Application Authority of the Law N°24.295.
National Arrangements	
166/01	S.D.S.y P.A. 16/08/2001 Creation of the National Program for Alternative Energies and Fuels in the ambit of the Secretariat for Environment and Sustainable Development.
167/01	S.D.S.y P.A 16/10/2001 New identification for the Argentine Office for Joint Implementation (OAIC).
168/01	S.D.S.y P.A. 16/10/2001 Technical Assessment Service for the projects presented to the Argentine Office for the Clean Development Mechanism (OAMDL).
169/01	S.D.S.y P.A. 16/10/2001 Approval for the procedure rules for the management of the projects presented to the (OAMDL).
Resolutions	
849/99	S.R.N.y D.S. 07/09/1999 Reglamentation for the Executive Board of the OAIC operation.
1076/01	S.D.S.y P.A. 08/08/2001 Creation of the National Bio-fuels Program in the ambit of the Secretariat of Sustainable Development and Environmental Policy (SDSyPA).
1125/01	S.D.S.y P.A. 16/08/2001 Creation of the National Program on Climate Change Impacts in the ambit of the SDSyPA.
1620/01	M.D.S. y M. A. 19/10/2001 Ratification of the Arrangements 167/01, 168/01 y 169/01.
345/02	S.A.y D.S. 04/06/2002 Format for the MDL project presentations to the OAMDL.
435/02	S.A.y D.S. 19/06/2002 Creation of the Registry of Evaluation Institutions in the ambit of the OAMDL.
56/03	M.D.S. 14/01/2003 Creation of the Climate Change Unit.
372/03	S.A.y D.S. 15/03/2003 Designation within the Climate Change Unit.
579/03	M.D.S. 18/03/2003 Designation of the president of the EXECUTIVE BOARD of the OAMDL.

Source: http://www.medioambiente.gov.ar/mlegal/clima/menu_clima.asp

Annex 9.2a AIJ projects approved by the Argentines Office of Joint Implementation (now OMDL)

All projects		Participants	Short description
1	Greater Buenos Aires (*) Landfill gas management Fugitive gas capture	Coordinación Ecológica Area Metropolitana Sociedad del Estado (CEAMSE) from Argentina and Pacific Energy Systems, Inc.from USA.	Involves the development of gas collection and combustion systems at landfills owned and operated by CEAMSE, a regional government agency. CEAMSE will install and operate a system of wells, pipes, blowers, and flares to recover and burn landfill gas (LFG) from the landfills it currently owns or will own in the future. CEAMSE is responsible for municipal solid waste (MSW) disposal in Greater Buenos Aires and the surrounding metropolitan area in Buenos Aires Providence. The project estimates that if 70 per cent of the gas generated by the five million tonnes of waste deposited annually in the CEAMSE landfills is collected and combusted, the project could result in an emission reductions of four million tonnes of carbon dioxide (CO_2) equivalent per year. Further reductions could be achieved through beneficial use of the gas.
2	Agua del Cajón (*) Combined cycle energy efficiency generation project	CAPEX, SA from Argentina and El Paso Energy International Company and International Utility Efficiency Partnerships, Inc. from USA	The project will install a heat recovery system and a steam turbine to achieve combined cycle operation at a 370 MW gas turbine power plant in Neuquén, Argentina. The effect will be to raise the capacity to 555 MW with no increase in fuel use or greenhouse gas emissions. The lower per unit cost of generation will increase the utilization of this more efficient plant under the local economic dispatch system that governs its operation, further reducing CO_2 emissions system wide.
3	Rio Bermejo Project (*) Forest preservation Carbon Sequestration	Fundación Proyungas and LIEY from Argentina LISEA TROPI-CO_2, Inc. (previously Project Reforesta Inc.) from USA	This is a sustainable management and forest protection project located in degraded mountain forest and agricultural lands in northern Argentina (Municipio de Los Toldos, Departamento de Santa Victoria, Provincia de Salta). The project will combine tree plantations in agricultural lands, enrichment planting and sustainable management in degraded logged forests, and forest preservation to increase carbon sequestration. The major goals of the project are to: sequester carbon to help reduce greenhouse gas emissions, protect biodiversity, and to offer local communities sustainable economic alternatives.
4	La Plata and Fontana Lakes basin Polluted Forest Recovery and Sustainable Management	PRIMA KLIMA, Germany – CIEFAP, Argentina	The objective is to protect the Native Forest of this Precordillera Andino-Patagónica area and to recover degraded Forest in La Plata and Fontana Lakes basin, by introducing forestall and cattle grazing sustainable managing techniques. To achieve the long run objectives it must be improved also the socio-economic condition of the local population. The project will introduce: Afforestation in irrigated areas; fire prevention and fire control tasks; new techniques for wood management in the long run; development and promotion of ecological tourism; infrastructure like roads construction will be built.
5	Forestall Project Alto River Chubut	COOPETEL	The objective is to sequester carbon through tree planting, in a profitable way, reducing the greenhouse effect and increasing wood production at the same time. The environment results also beneficiated by decreasing the water erosion in overgrazed fields.
6	Forestall Project Paso del Arco 797 Has.	CORFONE	The objective is to sequester carbon through tree planting, in a profitable way, reducing the greenhouse effect and increasing wood production at the same time. The environment results also beneficiated by decreasing the water erosion in overgrazed fields.
7	Afrorestation of Campo Nahueve	CORFONE	The objective is to sequester carbon through tree planting, in a profitable way, reducing the greenhouse effect and increasing wood production at the same time. The environment also benefits as there is a decrease in the water erosion in overgrazed fields.

All projects	Participants	Short description
8 Forestall Project El Boquete	Forestar Bariloche S. A.	The objective is to sequester carbon through tree planting, in a profitable way, reducing the greenhouse effect and increasing wood production at the same time. The environment results also beneficiated by decreasing the water erosion in overgrazed fields.
9 Forestall Project La Escondida	Jorge Roberts	The objective is to sequester carbon through tree planting, in a profitable way, reducing the greenhouse effect and increasing wood production at the same time. The environment results also beneficiated by decreasing the water erosion in overgrazed fields.
10 Forestall Project Jaramillo	Compañía de Tierras Tecka	The objective is to sequester carbon through tree planting, in a profitable way, reducing the greenhouse effect and increasing wood production at the same time. The environment results also beneficiated by decreasing the water erosion in overgrazed fields.
11 Forestall Project Jaramillo 547.39 Has	Compañía de Tierras Tecka	The objective is to sequester carbon through tree planting, in a profitable way, reducing the greenhouse effect and increasing wood production at the same time. The environment results also beneficiated by decreasing the water erosion in overgrazed fields.
12 Afforestation of Paso del Arco – Second Part	CORFONE/IUE	It is planned to convert about 4,250 hectares of this degraded soil into commercial plantations, through afforestation activities. Approximately 90% of them will be planted with Ponderosa Pine, the remaining 10% will be left for biodiversity protection, planting and/or protecting existing native species. Additionally this activities are considered to be quite efficient for carbon sequestration, fixing the C in the forestall biomass and emitting O_2 to the atmosphere during the growing and regenerating stages of the forest.
13 Forestall Project La Escondida – Second Part	Jorge Roberts/IUE	It is planned to convert about 180 hectares of this degraded soil into commercial plantations, through afforestation activities. Approximately 10% will be left for biodiversity protection, planting and/or protecting existing native species Additionally this activities are considered to be quite efficient for carbon sequestration, fixing the C in the forestall biomass and emitting O_2 to the atmosphere during the growing and regenerating stages of the forest.
14 Forestall Project El Neyen	Forestar Bariloche SA/IUE	It is planned to convert the most degraded land into commercial plantations, through afforestation activities. Approximately 10% will be left for biodiversity protection, planting and/or protecting existing native species. The remaining 90% will be planted with Oregon and Ponderosa Pine, which will be harvested periodically and finally used for obtaining high valued woods. Additionally this activities are considered to be quite efficient for carbon sequestration, fixing the C in the forestall biomass and emitting O_2 to the atmosphere during the growing and regenerating stages of the forest.
15 Forestall Project El Desafío	Forestar Bariloche SA/IUE	It is planned to convert about 46 hectares of the most degraded land into commercial plantations, through afforestation activities. Approximately 10% will be left for biodiversity protection, planting and/or protecting existing native species. The remaining 90% will be planted with Ponderosa Pine which will be harvested periodically and finally used for obtaining high valued woods. Additionally this activities are considered to be quite efficient for carbon sequestration, fixing the C in the forestall biomass and emitting O_2 to the atmosphere during the growing and regenerating stages of the forest.

(*) The fist three projects can be found in the UNFCCC Web page, List of AIJ Projects http://unfccc.int/program/coop/aij/aijproj.html among the projects which have been accepted, approved or endorsed by the Designated National Authorities for AIJ of the Parties concerned.

Annex 9.2b CDM Potential pre-feasibility Projects

	CDM potential pre-feasibility projects	Participants	Short description
1	Forestall Project west of Chubut Province	Without enough data	The objective is to sequester carbon through tree planting, in a profitable way, reducing the greenhouse effect and increasing wood production at the same time. The environment results also beneficiated by decreasing the erosion in overgrazed fields. About 3,500 hectares of cattle grazing will be planted with Ponderosa Pine.
2	Forestall Project south of Corrientes Province	Without enough data	The objective is to sequester carbon through tree planting, in a profitable way, reducing the greenhouse effect and increasing wood production at the same time. The environment results also beneficiated by decreasing the erosion in overgrazed fields. About 2,500 hectares of cattle grazing will be planted with Eucalyptus.
3	Energy efficiency project spreading efficiency lighting equipment for low-income argentines households	ELI quality seal administrators of Argentina	National programs for Energy Efficiency and production of emission reductions (ERs). The CO_2 emission reduction is obtained by spreading efficiency lighting equipment for low income Argentines households, together with a subsidy for purchasing.
4	Energy efficiency project efficiently using thermal energy in the food sector	Teacher of the Universidad Tecnologica Nacional – Fac. Reg. Santa Fe	Aimed to the implementation of Energy Efficiently activities used in the industrial sector, specially in the food branch. Aimed at lowering energy consumption, resulting in greenhouse gas emissions reduction, production of emission reductions (ERs)
5	Energy efficiency project cogeneration alternatives in the industrial food sector.	Teacher of the Universidad Tecnologica Nacional – Fac. Reg. Santa Fe	Cogeneration as a group of installations that allow a simultaneous generation of thermal electricity from a single source of primary energy. Cogeneration as rational energy use measures, makes a very large primary energy saving, due to the residual hot advantages. Cogeneration systems feature global efficiency of about 70%. This savings is highly incremented by using residual energy.

10. Country Study: Bangladesh

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A. Greenhouse gas mitigation opportunities

The following four studies dealing with greenhouse gas mitigation opportunities in Bangladesh have been conducted, but none of these studies have dealt with decentralized renewable energy in any comprehensive manner:

1. U.S. Country Study – Bangladesh Report (GoB, 1993)
2. ALGAS-Bangladesh (GoB, 1997)
3. TERI-Canada Energy Efficiency Project – Bangladesh report (BUET, 2002)
4. National Communication (GoB, 2002)

The U.S. Country Study is the oldest study dealing with GHG mitigation. It has dealt with mitigation opportunities in general terms and in broad sectors only. The ALGAS study was a very extensive study, but because of the lack of information on renewable energy potential, DRE projects have been dealt with in a superficial manner. It considered only three renewable energy options, namely, (i) Improved biomass cookstoves (ii) Improved biomass boilers and (iii) Paddy Parboiling. The focus of the ALGAS study was GHG mitigation on a least-cost basis from a national perspective. The ALGAS study predates CDM and no account was taken of the possibility of carbon trading. The TERI-Canada study was the first extensive study specifically dealing with CDM. The focus of the study was to find the best CDM projects predominantly based on cost effectiveness. The study, therefore, avoided all high-cost options, and in particular renewable energy ones. The National Communication did not do any primary investigation and merely reported the ALGAS study. With respect to renewable energy technologies, the National Communication makes the following remark—"Small-scale photovoltaic can be competitive, especially in remote areas with no grid access." In general, small-scale renewable in rural areas can be cost-effective and also reduce deforestation by reducing reliance on local biomass. Options include solar cooking stoves, biogas plants, small-scale wind systems, and small run-of-river hydro installations. Large-scale photovoltaic are not yet competitive against traditional generation in areas with a developed transmission grid. The National Communication emphasizes two things of significance to this study, namely:

(i) The need to reduce deforestation through the use of DRE technologies; and

(ii) Distributed small-scale technologies can be cost effective in off-grid areas.

It is noteworthy that the National Communication even emphasizes the use of fossil fuel technologies to reduce the reliance on wood and biomass. Similar suggestions have also been made in the National Energy Policy (GoB, 1996). The National Communication does not provide any indication of the potential of any renewable energy technology.

A few renewable energy studies are available. Some of these studies (Fulton, 2000; BCAS, 2003; Golam, 2003) show very high potential for renewable energy, while others show the potential to be very low. The conflicting opinions on DRE highlight one important fact, and that is, the data on, and understanding of, DRE potential is extremely limited. In such a scenario it is very difficult to assess the true potential. The only thing that can be said with certainty is that if some good projects are successfully implemented, then the true potential will gradually be revealed through replication.

Nearly all agricultural and animal wastes are utilized as fuels either for cooking or for rural industrial activities. This effectively limits its prospects as fuels for DRE technologies. The use of biogas from human excreta as a cooking fuel has to first overcome the social taboo. Using tree and plant biomass is difficult because even rice husk has an average price of US$17/tonne (US$2/GJ) at source. Firewood commands a price double that of rice husk. Moreover, if biomass is withdrawn from its present uses in the rural community, dangers of deforestation and other ecological problems may arise. The scope for energy plantations rather limited because land is extremely scarce. The following statistics will exemplify this fact—66 per cent of all land is used for agriculture, of which one-third is triple-cropped and one-half is double-cropped.

Many studies have shown that there is some potential of using wind and solar PV water pumping in the coastal belt, but the DRE technology that can have widespread application is Solar Home System (SHS). If the public utility known as the Rural Electrification Board (REB) adopts a favourable policy, then hundreds of thousands of these can be disseminated.

The low energy consumption of Bangladesh implies of course low GHG mitigation potential. However, since CDM is a project-based mechanism, there exists the possibility of identifying projects even under a low energy consumption scenario. Another important element of CDM is that it deals with energy consumption in the future, and since Bangladesh's energy consumption is growing at more than six per cent per year, this potential cannot be dismissed. One major problem in constructing CDM projects in the energy sector is that the large energy consuming industrial units are all in the public sector. Thus, there are GHG mitigation opportunities in cement plants, ammonia/urea plants, pulp and paper mills and sugar mills owned by the government. The private sector industrial units consume less than 15 per cent of the commercial energy. In addition, the consumption is scattered over numerous small industries. Furthermore, at the present market price of CERs the fossil-based energy sector mitigation options are very limited.

The forestry sector options are also limited because land is scarce, but cannot be dismissed outright because illegal felling and poor forest management have over the years left many designated forest areas denuded. In addition, the government owns land unsuitable for agriculture, which can be effectively used for energy plantation or afforestation programs. Social forestry, which involves community-based afforestation programs, has tremendous prospects in many areas of Bangladesh because there are now growing numbers of landless peasants. The government is serious about its afforestation and reforestation programs, but is unable to make much headway because of funds shortages and management deficiencies.

The most significant potential for CDM is in the waste sector, and landfill gas recovery and composting are the two leading sub-sectors. An UNDP-funded project has prepared business plans and drafted Project Design Documents (PDDs) on two landfill projects (one in the capital city Dhaka and one in the port city Chittagong) and two composting projects (one in Dhaka and one in Chittagong). It is expected that these four projects will be sent for validation. A snapshot view of these four projects is presented in Table 10.1. The local and international consultants engaged under the UNDP project found limited prospects for typical DRE technologies as CDM projects.

Table 10.1 The four waste sector projects developed under a UNDP project

Project	CO_2 eq. emission reduction (tonnes)	Total investment	Sustainable development benefits
Matuail landfill	990,000 in 8 years	US$3.5 million	Reduction of odor and fire hazard
Roufabad landfill	200,000 in 8 years	US$975,000	
Composting-Dhaka (700 t/day)	480,000 in 8 years	US$6.4 million	Reduction of odor, dust and fire hazard. Saving of land. Large number of jobs for women. Very high quality fertilizer (adaptation benefit by enhancing organic content of soils)
Composting-Chittagong (200 t/day)	138,000 in 8 years	US$2.6 million	

Source: Waste Concern (2003)

B. Involvement with AIJ and/or CDM activities

Bangladesh has no experience with AIJ or GEF funded GHG mitigation projects. At present, the following three GEF projects are being developed:

1. Bus rapid transit;
2. Efficiency improvement in brick kilns; and
3. Developing a sustainable and environmentally sound transport system for three South Asian Cities – Bangalore, Colombo, Dhaka.

With regard to the CDM, Bangladesh has been fairly active, and one study (BUET, 2002) has made preliminary identification of 15 projects in the energy sector with two of these developed up to the pre-feasibility level. Out of the fifteen projects, only one is a DRE project (water pumping using windmills). The Bangladesh University of Engineering and Technology (BUET researchers concluded that the prospects for conventional DRE projects are limited. In another ongoing effort, BCAS, an environmental NGO, is working on the following three projects:

1. 12-seater electric vehicles to replace 14-seater gasoline vehicles;
2. Solar Home Systems (SHSs) in rural off-grid areas;
3. Efficient lighting in rural areas (using compact fluorescent lighting).

These projects are being developed under the South-South-North network funded by the Netherlands Government, whose headquarters is in Cape Town, South Africa. The only other CDM-related activity is the UNDP project mentioned earlier. This project (March 2003 to September 2003) was executed with the following goals:

1. assist in forming the Designated National Authority (DNA);
2. capacity development of the institution that will be in charge of CDM;
3. awareness raising, particularly in the business community, of the prospects and opportunities under the CDM;
4. develop baseline for Landfill Gas Recovery project; and
5. develop policy guidelines and SD criteria for CDM.

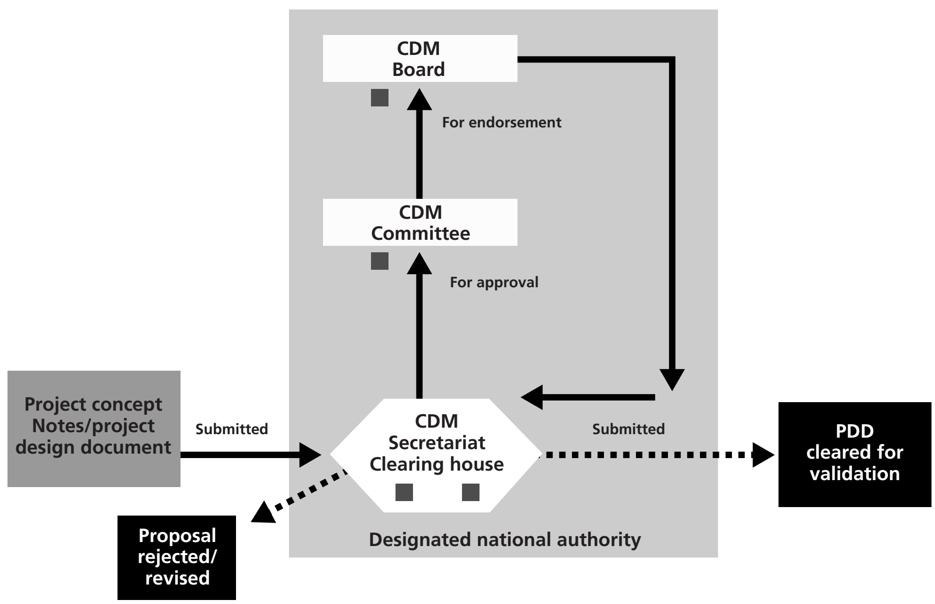
This project has been extremely successful. The government has accepted the report prepared by the consultants on the formation of the DNA, and has completed all the formalities for setting up the DNA. The sustainable development (SD) criteria being developed focuses predominantly on the most significant environmental issues affecting the country. The SD criteria does not specifically address adaptation issues, but because it deals with desertification and loss of soil quality, the adaptation issue gets incorporated indirectly because addressing these two environmental problems will make rural communities more resilient to the vulnerabilities of climate change.

C. Climate change institutions for mitigation and adaptation: capacity and capabilities

The Government of Bangladesh approved the establishment of the DNA in October 2003. The DNA chart is presented in Figure 10.1. Bangladesh has opted for a two-tier DNA structure. The first or lower tier, to be located at the Ministry of Environment and Forest (MoEF), is the secretariat or operational body of the DNA. It will perform all CDM-related activities including giving preliminary approval of CDM projects through the CDM Committee, whose composition is given in Figure 10.2. The second or upper tier, known as the CDM board, will give the final endorsement of the approved projects. The composition of the CDM board is given in Figure 10.3. The Principal Secretary to the Prime Minister will head the Board. Since the Principal Secretary has jurisdiction over all the other secretaries of the government, it is expected that interministerial complications will be smoothed out.

The DNA has been set up under the MoEF. This implies that there will be a strong focus on environmental issues in the approval process for CDM projects. In terms of the effects of climate change and the consequences on human beings, Bangladesh has been placed in the most vulnerable group. This has made the climate change focal point in Bangladesh very aware of the importance of adaptation to the vulnerabilities of climate change. It is expected that the DNA would try to integrate adaptation into the sustainable development criteria to be developed for evaluating CDM projects. The DNA being favourably disposed towards adaptation will encourage CDM projects that have adaptation co-benefits. Thus, a whole class of CDM projects that lower stress on environmental and natural resources, and constitute adaptation to the vulnerabilities of climate change, may be promoted through the CDM mechanism. The two DRE case studies presented in Part A of this report address deforestation and soil degradation, both of which are key climate vulnerabilities, fall into this category.

Figure 10.1 The DNA chart showing the CDM project approval process for Bangladesh



CDM policies and preparedness can be described to be in a fair to poor state, the predominant reason for this being the climate change focal point's inability to dedicate human resources to deal with this emerging area. However, many bilateral and multilateral donor agencies are very willing to assist the government in this regard. The redeeming feature of the focal point's human resource and capacity shortage is that they maintain good contact with environmental NGOs, universities and technical/research institutes. Most climate change studies have been government-NGO partnerships. As mentioned earlier, because deforestation and soil quality are burning environmental issues in the country at present, the formulated CDM policies will most certainly incorporate all kinds of DRE technologies that address these issues.

The sustainable development criteria being considered are expected to be based on the decision tree shown in Figure 10.4. The proposed procedure suggests that the DNA, after extensive consultation with all stakeholders, will prepare a list of urgent environmental concerns (and goals) and development plans (and goals). If a project does not violate any development plan, and is benign to the local environment it would be considered to have passed the first round of tests. After that, if it can be shown that the project strongly addresses even one environmental or development goal, then it will be approved. It is envisaged that approval using the simplified criteria of Figure 10.4 will be mainly applied to projects prepared by the government or government sponsored agencies. Private sector projects will be evaluated using a pair-wise comparison type SD criteria. The indicators of the criteria will be similar to those being proposed by different international NGOs working with SD criteria like the SSN and the World Wide Fund for Nature (WWF).

Figure 10.2 The composition of the CDM Committee for Bangladesh

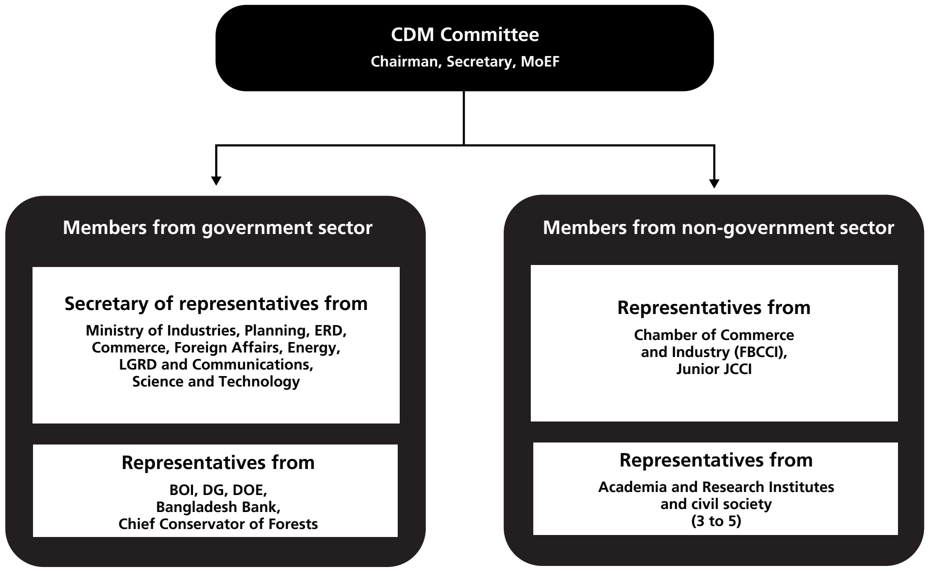


Figure 10.3 The composition of the CDM Board for Bangladesh

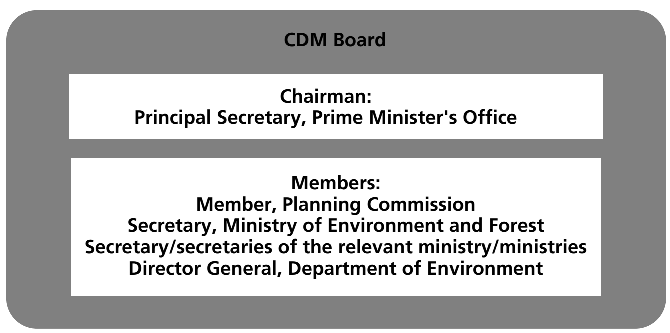
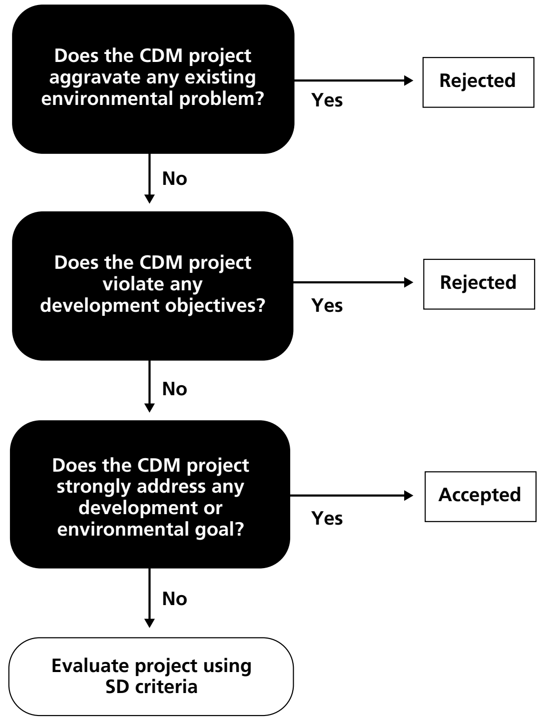


Figure 10.4 Decision tree for evaluating CDM projects



National CDM authorities look at SD criteria predominantly from the following three perspectives:

1. That they address some significant environmental problem;
2. Alleviate jobs and poverty; and
3. Advance some stated development goals.

The CDM SD criteria being considered will attempt to incorporate these aspects in the evaluation process. As the SD criteria stands now, it does not directly address the Delhi Declaration but from what has been said earlier regarding adaptation, in particular those related to deforestation and loss of soil organic content, the expectations of the Delhi Declaration will be adequately fulfilled if adaptation co-benefits can be realized from CDM projects. The SD criteria will be first formulated by a small group of CDM and sustainable development experts before it is placed with a much larger body of stakeholders for refinement.

In Bangladesh, the MoEF is coordinating vulnerability and adaptation activities with assistance from its technical wing known as the Department of Environment (DoE). The same institution is also responsible for mitigation activities. Bangladesh has been very active with vulnerability and adaptation. In October 2002, the UNFCCC's International Workshop on National Adaptation Programs of Action (NAPA) was held in Bangladesh. This has placed Bangladesh on centre stage with respect to vulnerability and adaptation. A high-powered NAPA committee has been formed and funds have also been secured to conduct a NAPA strategy. In this committee there is good representation from all stakeholders. The work to formulate the NAPA strategy will soon begin, and it is expected that a good strategy will be formulated.

The national government is preparing for climate change but the local governments are not aware of climate change. One reason for this is that the local government structure is very weak. Bangladesh is governed essentially by a strong central government. This style of governance works only because of geography, since Bangladesh is a very small country. All decisions of any substantive nature are taken at the capital, and the role of the local government is to execute the decisions.

D. Assessment of ability of CDM to support mitigation and adaptation through DRE

The MoEF, which is the climate change focal point, has seen its core activities double in the last five years and is unable to dedicate human resources towards climate change-related activities. Therefore, despite having all the good intentions regarding DRE, they are in no position to directly facilitate DRE CDM projects in Bangladesh.

A big barrier to promoting DRE projects through CDM is that DRE projects are under the purview of the Power Division (PD) of the Ministry of Energy (MoE), while CDM is under the MoEF. There does not exist any effective contact between the PD of MoE and the MoEF. The Power Division of the Ministry of Energy does have adequate capacity to evaluate DRE projects and are themselves involved in projects for promoting DRE. Had the responsibility to promote DRE CDM projects been with them, things would probably have moved faster. However, once the CDM process is activated through the DNA, it is expected that closer cooperation will result. As discussed earlier, the government agency most active with DRE is the Local Government Engineering Division (LGED). Since LGED is a partner of the MoEF in its SRE project, it is expected that the DNA (housed at MoEF) will seek appropriate assistance from LGED regarding DRE technologies. The inter-sectoral problems with mitigation/CDM projects have been reported from many countries. This is the principal reason behind the Asian Development Bank choosing the PD of the MoE for its "Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement (PREGA)" project.

The energy policy, formulated in 1995, contains many recommendations on renewable energy technologies, but no concrete steps have been taken in this regard. Purely from their own initiatives, NGOs and DRE vendors/suppliers are promoting renewable energy in Bangladesh. Local development agencies, NGOs and community groups are fairly active in developing DRE projects, but regularly complain at different forums of the lack of government support.

CDM is, by and large, an unknown concept to the promoters of DRE technologies in Bangladesh. Very recently the government through an UNDP-funded project has started an awareness campaign. It is expected that more and more CDM-DRE projects will be developed. It is however worth pointing out that at the present time CDM-DRE suffers from the following four shortcomings:

1. The potential for typical DRE technologies other than the PV has been identified to be low;
2. The complicated procedures for CDM;
3. The small level of CDM subsidy at the current market price of CERs. (It is estimated that only 10–20 per cent of the full cost of the project can come from CDM); and
4. The small-scale nature of the DRE technologies imply that these have to be bundled to have a reasonable size project.

It is fair to say that the potential of DRE technologies has not been assessed in any systematic manner. Moreover as newer technologies, which increase the efficiency of utilization become available in the future, the existing potential will naturally increase. The important issue is that the existing potential is not being harnessed. If CDM is correctly applied at least a dozen projects can be formulated.

The key to developing appropriate CDM institutional capacity is to foster a very good and strong linkage between government, environmental NGOs, technical institutes, equipment suppliers and business groups. The highly technical nature of CDM projects coupled with the elaborate requirements of the CDM process (PDD preparation, validating baselines, monitoring and verification of emissions, certifying CERs) imply that without good coordination amongst all the partners, DRE technologies cannot be promoted as CDM projects. The DNA must make extensive use of all the stakeholders to effectively promote CDM projects. In this regard, it is worth stating that many Bangladesh environmental NGOs and technical/research institutes possess excellent capacity in CDM. These entities have been playing an important role in the climate change and CDM processes for many years. At the present time, the human resources available at the climate change focal point are inadequate to promote the activities under CDM.

Eighty per cent of the 130 million people of Bangladesh live in rural areas where access to energy is extremely limited. The government is struggling to expand the grid to supply electricity, and biomass fuel is getting more scarce day by day. DRE projects can play a big role in supplying energy in rural areas. Many of these projects have large adaptation co-benefits. Two such examples have been presented as case studies. Five other projects, along with their adaptation benefits, are given below:

1. Improved biomass cookstoves – arrest deforestation and soil degradation;
2. Biogas plants – increase adaptive capacity through increased livelihood and arrest soil degradation;
3. Household waste composting – arrest land degradation;
4. Solar/wind groundwater pumping – alleviate drought effects; and
5. Efficiency improvement in parboiling – increase adaptive capacity through increased livelihood opportunities and arrested deforestation and land degradation by saving biomass fuel.

Renewable energy technologies in many more GHG reduction projects, especially innovative ones, that have climate change adaptation co-benefits, can be identified in the rural context. Access to energy by itself increases the adaptive capacity of rural people. More specifically, in the Bangladesh context, the conservation of biomass (and hence reduction of land degradation), increased and diversified food production and reduced deforestation (and hence reduced land degradation) can be achieved through well-designed CDM projects.

To develop well-designed CDM projects the following three ingredients are essential: capacity building, research and development and technology transfer.

Developed countries must play a pivotal role in these areas. Developing countries on their own cannot be expected to contribute much towards CDM project development without sustained financial, technical and capacity building support. The widely-articulated large potential of CDM projects will remain by and large untapped unless substantial resources are expended to develop innovative GHG mitigation projects.

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11. Country Study: Brazil

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A. Mitigation opportunities through decentralized renewable energy programs

Almost all urban households in Brazil have electric energy service and according to a recent survey 1,540,534 rural households do not, according to the Pesquisa Nacional por Amostra de Domicílios (PNAD, 2001). The IBGE Demographic Census (2000) estimated that there were 2,113,276 households in rural areas without access to this type of service. Furthermore, according to the census, about 11 million Brazilians live without electricity, scattered throughout rural and isolated areas. This characteristic causes electricity concession holders to be uninterested in providing the service, given the difficulty of extending the existing grid at tolerable costs and in a manner that is technically appropriate.

Decentralizing energy generation appears to be the solution that is most feasible for the problem. DRE presents the option for producing local electricity and provides flexibility for supplying energy on a small scale. In this context, the Brazilian potential for the use of renewable resources for the decentralized electricity supply while mitigating GHG emissions is considerable.

Some initiatives that will help take advantage of these opportunities should be mentioned. Law 10.438 of April 26, 2002, mandates universal access to public electric energy service while ANEEL Resolution 223 of April 29, 2003, regulates the aspects of such universal access, including establishing targets for fully supplying service throughout the country by 2015. These targets will lead to greater use of renewable energy resources, particularly in rural and isolated regions. The federal government's previously largest source for financing rural electrification was the Light in the Countryside Program (*Programa Luz no Campo*). The program did not exclude the use of decentralized renewable energy systems, but was based primarily on extending the conventional electricity network, which because of the Brazilian characteristic of using hydroelectric energy already has low GHG emission levels.

Other Brazilian programs have also contributed to the dissemination of renewable energies:

- *States and Municipalities Energy Development (PRODEEM):* its objective is to provide energy through local renewable resources to off-grid regions;
- *PCH-COM:* its objective is to foster the generation of electricity through small hydropower plants (SHPs); and
- *Alternative Energy Source Incentive Program (PROINFA):* it was created to increase the participation of wind, biomass and SHP energy in the national interconnected system.

A link between the use of renewable energy sources and the regulatory framework of the Brazilian electrical sector for providing universal access to rural electrification has clearly become inevitable.

The local exploitation of sources of renewable energy near to the consumers constitutes, perhaps, the main advantage for using DRE, since it permits both the connection of consumers to small off-grid networks as well as the creation of individual energy supply systems. Given the current state of technological development, the following renewable resources are the most propitious for generating electricity for the rural sector: biomass and solar resources, wind and hydroelectricity. The significant potential that Brazil has regarding renewable energy resources, and of fundamental importance for the mitigation of GHG emissions, is reviewed below (Oliveira, 2003).

Wind energy

The Brazilian wind atlas, prepared by the Eletrobrás Research Center (CEPEL), Ministério de Minas e Energia (MME) and Eletrobrás, estimates the energy potential at about 143 GW, as calculated using integrated digital maps for all of the areas with average annual velocities equal to or greater than six m/s.

Solar energy

"Brazil only loses out to the Sahara desert regarding solar potential" (Baldini, 2001). Ideally, insolation should be greater than five kWh/m^2/day during the year to fully take advantage of a solar panel. According to the Brazilian solar radiation atlas, the northeast region of the country contains areas with an average of approximately six kWh/m^2/day.

Small hydroelectric plants (SHPs)

Brazil's current electricity generation facilities are predominately based on hydroelectric sources. The physical characteristics of the country favour this type of generation, and there is still a vast exploitation potential. About 24 per cent of the total hydroelectric potential is currently developed.

Brazil's hydroelectric potential, according to the information stored in the Brazilian Hydroelectric Potential Information System developed by Eletrobrás, totals 258,420 MW. According to PORTO (2002) the potential that has been inventoried and under study for SHP development is about 9,794 MW and 1,530 MW, respectively.

Biomass

CENBIO estimates that Brazil has an electricity generation potential from sugar cane, wood and agricultural residues that varies between 12 and 27 GW. Considerable opportunity for using biomass in off-grid energy generation systems. For example, gas-fired micro-turbines for the generation of electric energy in isolated systems are being studied in a R$1 million research project between the Federal Engineering School of Itajubá (Efei/MG) and Companhia Energética de Minas Gerais (CEMIG). Different micro-turbines of up to 45 kilowatts using alcohol and gasified biomass as well as natural gas will be tested (http://www.energiabrasil.gov.br).

Vegetal oils

The main plants from which vegetal oils are derived in Brazil are the African Palm oil (dendê), macauba, mamona and "buriti." Two main projects have been developed in Brazil, both generating electricity for small communities, which produce the oil. One is a palm oil-fuelled engine in Vila Boa Esperança, in the state of Pará, and the other, an andiroba oil-fired unit in an indigenous village in the state of Amazonas. In both cases a multi-fuel diesel engine (Elsbett) of German origin is used, burning the oils "in natura." Funds for the oil extraction plant of Vila Boa Esperança came from the federal Ministry of Science and Technology, while the project in the indigenous village was funded by the ANEEL and is managed by the University of Amazonas.

Some vegetal oils have high nutritional and pharmacological value (such as the Brazil nut and some palm trees), and the choice of which one to use for biodiesel should not conflict with this market. The greatest difficulty in Brazil (and in other countries) is the high price of some vegetal oils: around US$400–500 per tonne for soybean oil or palm oil. The production cost reported in one of the commercial plants in Brazil was US$250/tonne (Silva, 1997 in WINROCK, 2002).

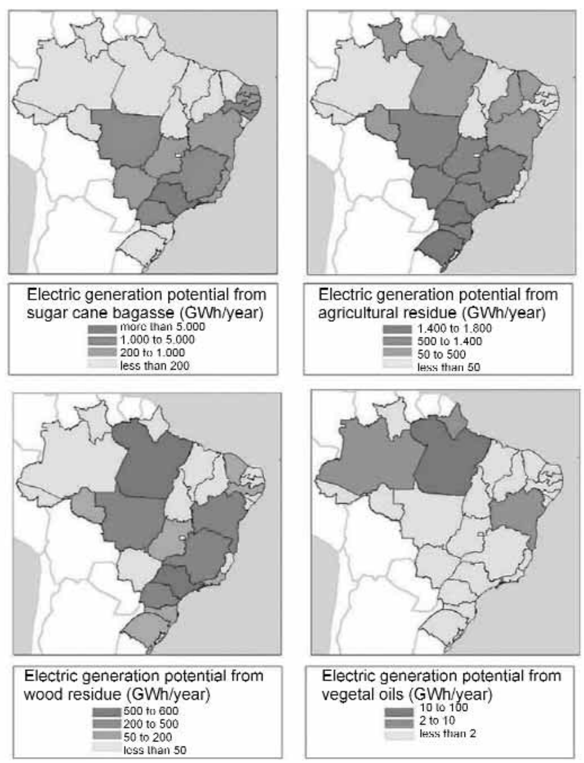
The Program RioBiodiesel from the Rio de Janeiro state government intends to use vegetal or animal oil to produce biodiesel to supplant diesel oil will be used in all vehicles belonging to the private and public enterprises associated with the RioBiodiesel Program. It is the first industrial-scale program of biodiesel production in Brazil. The Ministry of Mines and Energy and Eletrobrás are planning similar programs for the whole of Brazil.

GHG potential from DREs

Brazil will have substantial environmental and social gains at local levels by using renewable resources for rural electrification where such programs are technically and economically feasible. Global gains for the mitigation of climate change also are considerable. Although the individual contribution of rural residences in reducing greenhouse gas (GHG) emissions is small, the impact taken together is significant. Through its 2000 demographic census the IBGE estimated that there are 2,113,276 households in rural areas that do not have access to electricity. Using the formula to calculate the baseline for simplified modalities and procedures for small-scale projects accepted by the Executive Committee for the Clean Development Mechanism, and taking into account the diesel emissions factor adopted in these simplifications, the CO_2 emissions mitigation potential (based on diesel substitution) is in the order of 941,465 tonnes/year (Oliveira, 2003).

Electric energy generation from renewable energy is economically and environmentally possible in many locations, and it is also possible to use the Brazilian subsidies programs and CDM funds. There is a great biomass potential, as shown in the figure below.

Figures 11.1a–11.1d Brazil's electric generation potential by source



Source: CENBIO – National Reference Center of Biomass

Note: figure edited and translated by IVIG

B. CDM status and prospects

The 1980s and 1990s were years marked by a growing share of fossil fuels used in Brazil's energy sector. CDM project activities in the energy sector of Brazil are a way of helping reverse this trend, since renewable energy sources (in the form of sugar cane products, wood, urban solid and agricultural wastes, hydroelectricity, solar and wind resources), and potential efficiency gains in energy production/generation and transportation/transmission/distribution, are widely available.

Reforestation and afforestation projects within the CDM framework also have great potential given Brazil's climate and size. However, because of the complexity and the lack of definition about the modes and procedures governing reforestation and afforestation activities, Brazil does not have many projects that have been implemented in terms of land use change. What exists are sustainable biomass production projects that will supplant fossil fuels.

Several CDM project development activities and types are currently at different stages (under consideration, in preparation or ready to be submitted as a CDM project), which confirm the perception that the international business community sees Brazil as one of the most promising countries to host future CDM projects. These project activities are highly concentrated in three main mechanisms for carbon abatement: use of renewable energy sources, co-generation, and energy efficiency measures.

The World Bank's Prototype Carbon Fund (PCF) finances the Plantar project in the state of Minas Gerais, which is based on charcoal production from a forest plantation for a pig iron industry. The PCF also finances the NovaGerar project, located in the state of Rio de Janeiro, which consists of the use of biogas from a sanitary landfill for generating electric energy. Financing a portfolio of small-scale renewable energy projects is also under study.

The Netherlands government CERUPT (Certified Emission Reduction Unit Procurement Tender) also selected two projects in Brazil:

- The Catanduva biomass project, using sugar cane bagasse, (São Paulo)
- The Tremembe Onyx landfill gas project, Brazil-São Paulo

Also funded by the Netherlands government are:

- Fuelling garbage trucks with biodiesel produced from used vegetal (cooking) oils in Rio de Janeiro – HIDROVEG
- Power generation through biogas and biodiesel at the Jardim Gramacho Landfill, Rio de Janeiro – GRAMACHO
- Energy generation through the use of urban solid wastes from the Ilha do Fundão – Campus of the Federal University of Rio de Janeiro – USINA VERDE
- Processing urban solid wastes through DRANCO – Dry Anaerobic Composting – System to Produce Electrical Energy and Carbon Sequestration

Several projects have also been carried out by the De Rosa, Siqueira, Almeida, Mello, Barros Barreto e Advogados Associados (DRSAMBBAA) Law Firm. This law firm has been dealing with carbon trading issues since 1996/97, as the Brazilian arm of International Ernst & Young Law Practice Network. The company has co-generation and renewable energy projects in the state of Rio de Janeiro and states in Brazil's southern region.

Ecoinvest, a consulting firm based in Brazil, offers investors in the United States and Europe a portfolio of environmentally-friendly investments in Brazil that will provide competitive rates of return and at the same time are likely to generate CERs. The company has a biomass project in Amazônia, a co-generation project in São Paulo, a wind power project in Rio de Janeiro and a small hydroelectric plant (SHP) in Paraná.

Ecosecurities also runs projects that take advantage of biogas from landfills, the production of charcoal, small SHPs and co-generation using sugar cane bagasse. The projects are located in the states of São Paulo, Rio de Janeiro, Espírito Santo and in the northern region of the country.

Issued in November 2001 by the National Environmental Fund (FNMA) of the Ministry of Environment of Brazil, a call for proposals of climate change projects brought in 13 projects, five in the field of energy and eight for forestry. The funds to implement the projects approved by FNMA came from a bilateral accord between Brazil and the Netherlands designed to support local pilot projects in order to achieve technical, scientific and social development.

Despite the fact there have not been many CDM projects developed by NGOs, three studies should be mentioned that do have such participation and have gained visibility:

- The Instituto Ecológica is responsible for the establishment of the Carbon Sequestration Project on the Ilha do Bananal (PSCIB I);
- The SPVS carbon sequestration projects being carried out in partnership with the NGO, The Nature Conservancy (TNC); and
- The Pronatura Carbon Sink with the automobile producer Peugeot in Mato Grosso.

C. Climate change institutions for mitigation and adaptation: Capacity and capabilities

The Designated National Authority for administering the CDM in Brazil is the Interministerial Global Climate Change Committee, created by the President of the Republic by Decree on July 7, 1999. The authority is designed to articulate the government actions stemming from the United Nations Convention on Climate Change and its subsidiary instruments of which Brazil is a part. The chairman of this committee is the Minister of Science and Technology and the vice chairman is the Minister of the Environment, and its main attributes are the following:

- To issue opinions, whenever required, regarding sector policies, legal instruments and rules that contain a relevant component for the mitigation of global climate change and for adapting the nation to its impacts;
- To supply information that supports the Government's position in negotiations under the aegis of the United Nations Convention on Climate Change and subsidiary instruments of which Brazil is a part;
- To define the additional eligibility criteria to those considered by the Convention's organisms in charge of CDM, foreseen in Article 12 of the UN's Kyoto Convention on Climate Change, according to national sustainable development strategies;
- To take into consideration opinions written about projects that result in the reduction of emissions and that are considered to be eligible for CDM, referred to in the previous item, and to approve them, if it is the case; and
- To discuss together with representatives of civil society ways of fostering action by government and private entities to comply with the commitments assumed by Brazil under the United Nations Convention on Climate Change and the subsidiary instruments of which Brazil is also a part.

Despite the fact that one of the Committee's objectives is to define additional eligibility criteria beyond those considered by the Convention Entities, according to national sustainable development strategies, that is not what this commission has as yet. The Ministry of Science and Technology (MCT), which chairs the commission considers that the establishment of the criteria beyond those that already exist internationally would wind up causing a loss in competitiveness for the CDM project activities that could be established in Brazil. This is because of the greater cost that they would require compared to other countries. For its part, the Environmental Ministry (MMA) believes that Brazil would become more attractive by establishing sustainable development criteria.

The MMA, through the authority vested in the vice chairman of the committee, is making an effort for the adoption of criteria that promote sustainable development through the CDM. The Ministry has prepared a proposal of criteria and indicators for evaluating CDM Candidate Projects, which it intends to use to support the actions of the Interministerial Global Climate Change Committee. This document was delivered to the aforementioned commission and was the topic of the seminar entitled "CDM and Sustainable Development" held on December 20, 2001 (Brasilia-DF). The committee has still not regulated the CDM in Brazil.

The establishment of the Interministerial Global Climate Change Committee, which is the Designated National Authority in Brazil, is a fundamental step for the development of institutional capacity regarding CDM. The purpose of the Interministerial Committee is to articulate government action deriving from the Climate Change Convention and the subsidiary instruments to which Brazil is a signatory.

Despite these preparations, there is still a lack of understanding within the business sector about approval of projects by the Interministerial Global Climate Change Committee. On a wider level, there still is the need for internal regulation of the Clean Development Mechanism, which by its very nature is highly complex. The lack of definition regarding internal rules has been the cause of concern on the part of the business sector regarding development of projects, since such a situation increases investor risk.

Decentralized renewable energy projects within the CDM can generally be classified as small-scale, and do not attract much investor interest. It is, therefore, urgent that the entire Brazilian CDM governance structure previously described begin to consider more seriously these types of projects since there is major social/environmental appeal associated with DREs. The public or private initiatives need to incorporate responsibilities that permit making access to new technologies more democratic.

The implications of the simplified CDM procedures and modalities for small-scale projects, on DRE project in Brazil must be studied. The strengthening of local operating entities and the search for new unilateral projects depends upon internal measures. In the case of Brazil, there is a need for greater involvement on the part of rural electrification cooperatives, and it is up to the government to formulate public policies to make them CDM-capable. NGOs have an important role to play in this sense.

One of the attributes of the Interministerial Global Climate Change Committee is to establish national criteria for the evaluation of CDM projects that are additional to those formulated by the CDM Executive Council. Nevertheless, as already mentioned, some government sectors believe that national approval of the projects must be as simplified as possible so that the country does not lose competitiveness compared to other nations. However, there are other sectors that defend the idea that establishment of national sustainability criteria will attract investors interested in the socio-economic-environmental aspects associated with Certified Emission Reductions, precisely because of this distinction.

The process for the adoption of sustainability criteria by Brazil continues forward, a controversial topic both internally and externally. Based upon the Brazilian experience, it is recommended that the criteria first be established nationally, since the approval of the projects with respect to their contributions to sustainable development is a prerogative of the Designated National Authority. The involvement of the representative sectors of society is of fundamental importance so that the criteria truly reflect the desires of these sectors regarding CDM projects.

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12. Country Study: Senegal

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Climate change mitigation and adaptation concerns, being indissociable from sustainable development, should place priority on less-polluting energy sources and on decentralized renewable energy in particular. Moreover, the Clean Development Mechanism could offer investment opportunities for energy supply services, within the context of greenhouse gas reduction, sustainable development and improvement of the adaptation capacity of vulnerable groups to the adverse effects of climate change.

The current applications of decentralized renewable energy, however, are subject to rather high transaction costs, which reduce their accessibility and elevate the cost of this type of greenhouse gas reduction.

With regards to the implementation of the Clean Development Mechanism, some countries have received assistance in capacity building to establish the appropriate institutional arrangements and develop a portfolio of projects. Since examples of CDM projects are rather limited in Africa, lessons will have to be drawn from decentralized renewable energy demonstration projects introduced under a developmental framework or as jointly implemented projects so as to attract investments under the CDM.

Financing opportunities, available through the Global Environment Facility, state grants or subsidies, overseas development assistance, revision of the debt burden, for example, could also be leveraged for investments, thus making renewable energy more accessible.

Senegal ratified the United Nations Framework Convention on Climate Change and the Kyoto Protocol and is, therefore, eligible for CDM investment through the Kyoto Protocol. Under this framework, the country benefits from the assistance of the international community in executing several projects involving capacity building, implementation of the agreements of the convention and protocol, and developing projects based on renewable energy, aimed directly or indirectly at climate change mitigation and/or adaptation.

A. Greenhouse gas mitigation opportunities

The net emission figures for Senegal for 1994[1] were estimated at 3,321 Gg CO_2, for a population of 8.1 million inhabitants, that is 408.3kg CO_2/capita/year, or 1.12 kg CO_2/capita/day. The distribution of CO_2 emissions per sector is given below.

Table 12.1 Emissions from key sectors (1994)

Sector	Emissions/sequestration (Gg ECO_2)	%
Energy	3,788.6	40.6
Agriculture	2,957.6	31.7
Wastes	2,226.2	24.0
Industrial processes	345.5	3.7
Forests	-5,997.0	64 (capacity of sequestration)

Source: Communication Initiale du Sénégal : Minisrère de l'Environnement et de la Protection de la Nature

The distribution of emissions emanating from energy sources is as follows: industrial sector 44 per cent, transportation 32 per cent, household and other sectors 24 per cent. Mitigation strategies were, therefore, concentrated around energy efficiency programs and reinforcing the sequestration capacities of forests.

Table 12.2 Distribution of CO_2 emissions in the energy sector

Sub sector	Total GHG emissions (Gg)	% ECO_2
Industries	1,658.1	44
Transport	1,233.0	32
Household sector and others	897.5	24
Total	3,788.6	100

Source: Communication Initiale du Sénégal : Ministère de l'Environnement et de la Protection de la Nature

The opportunities for emissions reduction, as specified in the national implementation strategy of the climate convention are as follows:

- energy efficiency in buildings;
- energy efficiency in the industrial sector (the emissions reduction potential of key industries, such as SENELEC and SONACOS, is estimated at 90,000 t CO_2/year);
- rationalization of the transportation sector;
- promotion of new and renewable energy;
- carbon sequestration through the rehabilitation of degraded lands and other natural ecosystems, application of participative management of natural resources;
- intensification of sylviculture on irrigated farmlands for increased wood production;
- development of natural forests for increased fuelwood and charcoal production;
- establishment of small-scale enterprises (charcoal production enterprises);
- production and diffusion of improved stoves; and
- improvement of the butane gas distribution network.

The possible options identified in the regions of Tambacounda and Kolda are as follows:

Table 12.3 Mitigation options

Options	Total quantity of carbon sequestered (tonne)	Average quantity of carbon sequestered (tonne)
Tambacounda		
Reforestation rotation of fruit trees (250 ha)	359,249	59,874
Reforestation/rotation of eucalyptus (250 ha)	413,202	27,546
Forest protection (199,875 ha)	1,012,800,125	33,760,004
Kolda		
Protection (2,100,000 ha)	14,042,493,686	468,083,122

Source: Communication Initiale du Sénégal

B. Historical involvement with AIJ/CDM and current status of national authority and CDM activities

Institutional framework for climate change mitigation activities

Senegal has still not benefited from any activities implemented jointly (AIJ) or CDM projects. However, an institutional framework has been set up to coordinate such activities (Moussa Kola Cissé and Youba Sokona, 2000).[2]

The Ministry of the Environment and Natural Protection is the competent authority responsible for the implementation of the UNFCCC, and represents the government at all statutary meetings. The Department of the Environment, under the auspices of the Ministry of Environment, acts as the national focal point for the UNFCCC. The National Meteorological Department is the focal point for the Intergovernmental Panel on Climate Change (IPCC).

The National Committee on Climate Change, which is responsible for the coordination, definition and orientation of Senegal's national strategies on climate change has been established since 1997. This committee is composed of several ministerial departments, the private sector, research centres, the university and NGOs.

The committee's presidency, formally run by the president's office, is now under the responsibility of the private sector. This emphasizes the evolution of climate change negotiations and the necessity for the private sector to seize the opportunities offered by the CDM. The committee's secretariat is run by the Department of the Environment.

Under the implementation of the CDM, and in conjunction with the National Committee on Climate Change and the Department of Environment, Senegal has decided to set up technical and scientific sub-committees to assist and advise the National Committee. Energy and Carbon Sequestration sub-committees have been established. These committees' secretariats are equally run by the Environment Department.

Adaptation institutional framework

According to the Senegal National Action Plan for Adaptation (NAPA) Project document,[3] the Ministry of Environment and Natural Protection will be the focal point through the Department of Environment. A NAPA Multidisciplinary Integrated Assessment Network will be set up based on the National Climate Committee which prepared the Initial National Communication. Key sectors that will be represented in the country network include agriculture, health, water, tourism, transport, environment and energy. In addition, experts from each of the major ecosystems of Senegal will be included in the national network.

Some of the key organizations that will be represented on the NAPA Multidisciplinary Integrated Assessment Network include:

- Ministry of Agriculture and Stockbreeding
- Ministry of Mines, Energy and Hydrology
- Ministry of Fisheries
- Ministry of Tourism
- Ministry of Environment and Natural Protection
- Ministry of Industry and Handcraft
- Ministry of Finance and Economic Affairs
- Ministry of Public Health
- Ministry of Urbanism
- Ministry of Infrastructure, Equipment and Transport
- Ministry of Budget and Planning
- University Cheikh Anta Diop
- ENDA
- University Gaston Berger
- Council of NGO in Support of Development

Climate change related activities

The majority of activities undertaken in relation to climate change involve capacity building. The following activities deserve special mention:

- The UNEP/GEF Project for the implementation of the first assessment of greenhouse gas emissions (1993–1994). This project carried out the GHG inventory for 1991, and built national capacities to apply the 1994 version of IPCC guidelines for national GHG emissions inventories.
- The UNEP/GEF Project on mitigation analysis assessed the socio-economic development framework of the country, established the energy balance and updated the assessment of GHG emissions. Some mitigation options were raised such as: increasing carbon sequestration capacity through programs of afforestation/rotation and forest protection in Tambacounda and Kolda region (see paragraph 2.3.1); integrating renewable energies in the electrification policy through

decentralized electrification, pumps for rural hydraulics, electrification of community and administrative facilities; introducing energy efficiency in industries (energy companies, national company for oilseed products, chemical industry).

- The Netherlands Assistance Project on Climate Change which developed a climate scenario used in vulnerability and adaptation studies for coastal zones and agriculture. The study concluded that Senegal will face erosion, salinization of land and water, degradation of plant cover and reduce fish catch. The socio-economic impacts will be tremendous in terms of population affected and their agricultural activities.
- UNITAR CC: Train Project/UNDP/GEF which was focused on training, sensitization and support for the preparation of vulnerability studies (water resources) and the national implementation strategy. A national committee on climate change was set up. The vulnerability study revealed a deterioration in quality and quantity of water resources, with a drastic depletion of water tables and a failure of surface water flow.

Some other specific projects were undertaken in the context of climate change, desertification and energy access, such as:

- The ENERBAT-UNDP/GEF project on efficiency in buildings helped develop an energy efficiency code for commercial buildings, a thermal comfort code for housing; rehabilitate older buildings in order to demonstrate the feasibility of energy efficiency; and, elaborate a project portofolio.
- A sustainable management and participatory project on traditional energy and its alternatives (PROGEDE) that aimed to rationalize household energy, which was coupled with a forest management policy for woodfuel production.

Specific projects in the context of Kyoto Protocol

In the framework of the Kyoto Protocol, the following initiatives were undertaken:

- The UNIDO case study on building capacities in the industrial sector related to CDM: This project, in addition to identifying the constraints facing industries in Senegal, has chosen two plants for CDM project development. The portofolio of projects included diversification of energy through hydroelectricity, gas turbines, new and renewable energies and plant waste.
- The Start-Up CDM in ACP countries (SUSAC): This initiative aimed to “kick start” the CDM process in Senegal, Uganda and Zambia by identifying, developing and promoting pilot CDM projects that encourage new approaches to technology transfer, investment and economic growth.

It was envisaged from that these projects would lead directly to the implementation of real CDM projects ready for investment. This clear focus on specific CDM projects enabled capacity-building activities to be based on a “learning-by-doing” approach that ensured participants would gain practical experience in CDM implementation through a combination of research, workshops and training activities.

As a result of this approach, methodologies were developed and a portfolio of projects was brought out. Methodologies were developed for:

- CDM project identification – preparation of technical design documents;
- Evaluation of CDM projects – consideration of sustainable development and viability of project;
- Baseline calculation – evaluation of which method should be used to calculate the baseline scenario for the CDM project and what tools were most useful; and
- Monitoring and Verification Plan (MVP) – an essential document required by the UNFCCC for all CDM projects.

A total of six pilot projects were identified and due to barriers, which included high transaction costs, project finance (small-size projects in need of small amount of investment) and risks, only four of the six projects were considered viable. In addition, a climate change institutional framework has been established or defined in the participating countries—one of the SUSAC project objectives was to facilitate the creation of a national CDM secretariat.

Biocarbon Fund projects are also being developed. The projects identified concern the impact of intensified production systems on carbon sequestration and soil fertility; rehabilitation and reforestation of abandoned mines; sustainable production of charcoal; use of solar water pumping and micro-irrigation for forestry and horticultural production; fixation of dunes; and, carbon sequestration in agriculture.

C. Towards policy coherence: integrating DREs and the CDM within the development agenda

Development policies and DRE

Senegal, like most of the Sahelian countries was quick to recognize the importance of DRE in economic and social development. For more than three decades, Senegal's development policies have been oriented, not only on establishing macro-economic stability, but also on the search for a sustainable ecological balance, in order to overcome the constraints imposed by drought and desertification. To this end, energy and forestry policies have placed the emphasis on domestic fuels and on the rational and participative management of natural resources.

Decentralized renewable energy (DRE) has always been recognized as a credible alternative in strategies aimed at providing local populations with access to alternative energy sources, while preserving the environment. Several initiatives undertaken under the framework of sustainable development, have contributed towards GHG emissions mitigation, increasing sequestration capacities, and developing the adaptive capacities of local populations. Projects such as PROGEDE's butanization project, construction of solar energy stations, wind energy installations, improved wood and charcoal stoves, multifunctional platforms and reforestation, fall under this framework. Energy sector reform, initiated by Senegal, which emphasizes decentralized rural electrification, is indicative of the rising importance and interest in DRE. This is all the more reason why mitigation options for greenhouse gas emissions, as specified in Senegal's first communication, prioritize DRE and sequestration, while identifying DRE projects as potential CDM projects.

The document "Strategies for Poverty Reduction in Sénégal"[4] recognizes the intersectoral connection between energy and the other socio-economic sectors. This document emphasizes rural electrification as fundamental in meeting the energy needed by rural populations to satisfy basic needs and vital activities, such as: water pumping, irrigation, food conservation, processing of agricultural produce, creation of income generating activities (SME /SMI), and improving the quality of life of rural populations.

It is also hoped that the energy sector's global development strategy will lead to poverty reduction and will enhance the development of decentralized renewable energy (DRE). The priority areas of this strategy include: the development of production capacities, development of energy infrastructures and services by involving the private sector, village associations and local communities; financing the energy sub-sector, diversifying energy sources, improving the access of local populations to domestic fuels and intensifying rural electrification.

The development of a national action plan[5] derives from a recognition of the important role of the energy sector in the fight against poverty. This action plan places much priority on increasing the level of rural electrification, equipping households with improved wood and charcoal stoves, continuing the process of butanization, promoting the Casamance coal production kit, and diversifying domestic fuel.

These activities are consistent with the action plan outlined in the national report on sustainable development,[6] which promotes energy programs in rural areas, based on renewable and alternative energy sources.

There is still a need for global coherence between the different strategic plans proposed by the international community and the various national sectoral plans. CDM projects based on DRE should be viewed within this perspective and should satisfy Senegal's sustainable development priorities, on the basis of specific indicators and depending on the project, the policy and the aspirations of national stakeholders.

CDM potential for supporting mitigation and adaptation through DRE

Senegal has an institutional capacity and sufficient expertise to formulate DRE projects from a development perspective. However, capacities are limited for CDM and adaptation projects due to a lack of experience with these kinds of projects and climate change policy. CDM and adaptation are largely unknown concepts amongst the promoters of DRE technologies. The climate change focal point and the National Committee have a very low capability to promote CDM activities and adaptation projects. Only ENDA and some other NGOs are involved in local development projects and they are not very involved in climate change issues.

For a better understanding of the CDM and adaptation nexus through DRE, there is a need for capacity building. The steps which should be taken include:

- A comprehensive climate change policy linked to development priorities;
- An institutional framework integrating the adaptation and mitigation processes to deal with adaptation and CDM projects;
- Strengthening capacities in national institutions, industries, NGOs, universities and CBOs; and
- Strengthening the UNFCCC focal point.

Sustainable development criteria for CDM

Although Senegal has not developed a sustainable development policy for the CDM, steps have been taken to come up with generic sustainable development (SD) indicators and targets that could be used to develop CDM sustainable development criteria. All development projects should comply with national development priorities, and are generally consistent with the objectives of the Delhi Declaration. They are based on environmental, economic and social development with a special emphasis on poverty reduction as follows:

- *Economic indicators:* contribution to the GDP, reduction of exports, increase of foreign money, economic add value;
- *Social indicators:* job creation, income generation, human capacity building, poverty alleviation; and
- *Environmental indicators:* avoiding pollution, CO_2 reduction or sequestration, health preservation, sustainable use of natural resources.

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1 Communication initiale du Sénégal – Ministère de l'Environnement et de la Protection de la Nature.

2 Confronting climate change: Economic Priorities and Climate Protection in Developing Countries.

3 Proposal for funding for the preparation of a National Adaptation Programme of Action (NAPA), Senegal.

4 Sénégal : Document de stratégie de réduction de la pauvreté, mars 2002.

5 Banque Mondiale/ESMAP & ENDA : Synthèse du rapport Atelier multisectoriel, Energies modernes et réduction de la pauvreté (4 au 6 février 2003, Dakar).

6 Sénégal : Sommet Mondial sur le développement durable, Rapport National, Johannesburg 26 août au 04 septembre 2002.

13. Country Study: Zimbabwe

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Interest in the Clean Development Mechanism (CDM) in Zimbabwe is high. Zimbabwe views the CDM as an opportunity to receive much-needed foreign investment that would upgrade the capital base with state-of-the-art technology and attain sustainable development in the process. There exists also the widespread perception that Zimbabwe and Southern Africa in general are underdeveloped, which exacerbates climate change vulnerability. The CDM is, therefore, regarded as an opportunity to link climate change financing to basic sustainable developmental objectives.

The urban industrial base in Zimbabwe is strong by regional standards but capital stock is generally aged, and the CDM presents an important opportunity to attract much needed foreign investment and technology transfer. The degree to which national CDM priorities and project criteria are aligned with national sustainable development priorities is not yet clarified. The National Conservation Strategy (NCS, 1987),[1] developed in the mid-1980s details the high priority development criteria. The NCS identifies overgrazing and burning of non-arable lands is the most serious cause of environmental degradation in the country. Deforestation from land clearing, and increasing fuelwood demands are also cited as major threats. The NCS sustainable development priorities are particularly salient in the current context of climate change, which is projected to exacerbate land degradation through increased hydrologic stress. Within this context, the CDM is viewed as a potential complement to sustainable development priorities for Zimbabwe, as it can promote increased mechanization and intensification of agriculture and thus improve food security for the rural poor.

A. GHG mitigation opportunities

Zimbabwe ratified the Kyoto Protocol and in 1998 submitted its first national communication to the UNFCCC. The National Communication Process studies in Zimbabwe have highlighted the opportunities for climate change mitigation in the various sectors of the economy, and build on energy efficiency, renewable energy and efficient resource use studies (including the NCS) that pre-date the UNFCCC.

The assessments carried out since 1992 have consistently highlighted energy efficiency improvement, fuel switching and improved agricultural practice as the major mitigation options. Table 13.1 is a list of mitigation options that have been assessed, albeit with limited information.

The emission reduction cost changes with exchange rates, technology improvement and general economic environment. The cost figures in Table 13.1 are therefore valid for the year of study and would have to be updated. However, the other technical performance figures remain correct. The studies have not been updated since the first National Communication submitted to the COP in 1998. The CDM projects currently under discussion include:

- Electricity from wood waste for a sawmill;
- Electricity from sugar bagasse;
- Electricity from urban sewage gas;
- Electricity from small hydro plants; and
- Industrial energy use efficiency and industrial process efficiency.

Table 13.1 Carbon emission mitigation options in Zimbabwe

	Reduction option	Z$/tonne CO_2	Unit size	Unit type	Energy type saved	Equivalent emission reduction tonne CO_2/unit
1	New ethanol plant	-5,933.3	1	plant	gasoline	47,029.0
2	Tillage	-3,929.4	1	tractors	diesel	18.5
3	Efficient lighting	-4,223.2	1,000	bulbs	el-coal	54.1
4	Geyser time switches	-309.1		units	el-coal	1.3
5	Coal bed ammonia	-662.4	83	MW	coal	808,131.3
6	Methane from sewage	-542.2	1	plant	el-coal	1,203.8
7	Cokeoven gas for Hwange Power Station	-2,987.6	15,000,000	1 diesel eqv	diesel	43,941.9
8	Prepayment meters	-409.3	200	units	el-coal	1.9
9	Efficient motors	-459.3	1,000	kW	el-coal	4.3
10	Efficient boilers	-23.0	100	tonnes	coal	1,051.4
11	Savings in industry	-14.0			in-split	
12	Efficient tobacco barns	0.1	1	barn	coal	639.7
13	Pine afforestation	9.9	1	ha	wood	29.4
14	Biogas from landfills	0.0	1	landfill	el-coal	16,425.0
15	Efficient furnaces	-1,407.1	2	MW	coal	7,241.7
16	Biogas for rural households	48.0	1	digesters	wood	9.1
17	Hydro power	388.7	1	kW	coal	8.2
18	Solar geysers	-519.7		units	el-coal	2.9
19	Central PV electricity	2,702.4	1	kW	coal	2.1
20	Power factor correction	31,075.8	1	MVAR	el-coal	778.5
21	Solar PV water pumps	127,746.3	3.5	kW		0.2

Exchange rate: Z$12.00 = US$1.00; 1997

Source: (CDM Capacity Building for the Private Sector in Southern Africa, Zimbabwe Study, IER Germany et al., African industry and Climate Change, Project Proceedings, UNIDO, 1998.]

Although reducing fuelwood use and tree planting remain the most important rural development priorities because of their direct link to increased climate resiliency and the food security of the rural poor, no CDM project that addresses these objectives has yet been proposed. Decentralized renewable energy projects (DREs) that directly supplant fuelwood use such as biogas digesters, solar cookers and efficient wood stoves are all regarded as viable but have received little interest as potential CDM projects. Furthermore, DRE technologies such as solar PV and wind power that provide energy to intensify agriculture production, increase food security and indirectly contribute to environmental protection have also attracted little attention from CDM project developers.

The climate change/CDM community generally views dispersed rural energy projects as unfavourable as CDM projects. The main reason being the cost of establishing and monitoring these projects and the risk of the eventual emission reduction credits. In most cases, technologies such as solar cookers, biogas digesters for households and fuel switching to biomass-based liquid fuels raises questions regarding monitoring costs which discourage potential investors. The simplified methodology for small-scale projects does alleviate these fears but is not sufficient for encouraging very small or micro projects that would have a more immediate benefit for individual households. It appears that simplified methodologies for small projects will benefit the industrial community before individual rural households.

B. Involvement with AIJ and/or CDM

Projects implemented in the region have focused mainly on building capacity in the respective countries to identify and develop potential CDM projects. Zimbabwe has participated actively in the UNFCCC process through conferences, workshops and other such international forums at ministerial and other levels. Besides that, the country has participated in a number of studies, some ongoing, concerning the CDM and other climate change-related issues.

So far, Zimbabwe has only approved one AIJ project, a mini-hydro project on the Manyuchi Dam in South Eastern Zimbabwe. The investor for this project is the E7, a consortium of electricity utilities from OECD countries. Approval for this project took two to three years partly because there were no streamlined domestic procedures for AIJ projects in Zimbabwe. In general, the AIJ benefited other regions more than it did Africa, primarily because of the continent's lack of preparedness on project administration.

While no CDM project is currently underway in the region, a number of projects have been identified as potential CDM projects and are currently being developed. Initiatives by multilateral and bilateral organizations have helped create CDM capacity in the region. Table 13.2 shows some of the initiatives that have since been completed and some of which are currently underway.

Table 13.2 CDM-related studies carried out in the region

Project	Focal area	Objectives
EU Synergy; CDM and SAPP Zambia, Mozambique, Swaziland, RSA, Botswana and Zimbabwe	Power Sector/SAPP Security of supply	CDM Implementation capacity Information exchange Guidelines and templates Directory of business and contacts Web site
CIDA- CCCDF; Emission reduction RSA, Zambia and Zimbabwe	Sustained emission reduction in industry	Industrial capacity to identify CDM projects Assessment of negative cost opportunities – voluntary emission reduction. Engineering training – capacity building CDM Project Bundle
Dutch NCCAP; Barriers to win-win technologies	Industry and energy	Assessment of win-win opportunities Identification of barriers – project by project Draft barrier removal strategy

The lessons learned so far mainly relate to capacity building; a major barrier is the dissemination of information on CDM. Much work still needs to be done to effectively disseminate climate change and CDM information to all sections of society, especially local industry. Some of the capacities still required for the success of CDM include:

- Strengthening national UNFCCC focal points;
- Improving the understanding of the CDM, including the role and responsibilities of government, bilateral and multilateral arrangements and baseline determination;
- Capacity building for technology transfer;
- Providing an enabling environment for technology transfer to the private sector; and
- Capacity building for public awareness, coordination and cooperation, and improved decision making.

Although the government has played its part, industry has not been very responsive to climate change issues. Climate change, and hence CDM, issues have remained peripheral issues in policy formulation as there are other critical and urgent issues the country that the region has to grapple with. These issues include grinding poverty, drought and floods, collapsing health delivery systems coupled with increased pressure due to AIDS pandemic, high demand of social services like education, etc. Thus, one can say the urgent has overtaken the important in the allocation of resources towards climate change activities in the region.

C. Climate change institutions for mitigation and adaptation

Local CDM institutions

Zimbabwe ratified the Kyoto Protocol and in 1998 submitted its first national communication to the UNFCCC. It is in the process of compiling its second national communication to the UNFCCC, but the country has no institutional framework in place to aid the national CDM process. This is the case despite the fact that the country has solid institutions in place that need only some reorientation to be in a position to handle CDM business. With assistance from international organizations, the government in 1999 established the Climate Change Office. The central role of this office is to implement climate change projects in the country as well as to provide climate change-related secretarial services to the government ministries and the public. Research organizations, industrial bodies, financial institutions, NGOs, and industrial support services providers are all in place to take part in formulating a national CDM authority.

The Ministry of Environment and Tourism in Zimbabwe, with support from the climate change office, represents the country on international climate change negotiations. Other NGOs participating in different projects also attend UNFCCC meetings where applicable. Due to financial constraints, a limited number of climate change negotiators from the country and the region attended these negotiations. Coupled with this, there is a general dearth of information exchange between the local climate change negotiators and local industry, utilities and projects developers. Local potential project developers are not effectively represented in international negotiations. Those that are tasked to represent the country at the negotiations have so many issues to articulate that they are not able to fully represent their country.

The government, upon realizing the limitations of resources in disseminating the results of the negotiations and enabling all stakeholders to attend the negotiations, has used every available forum to engage all stakeholders to take part in climate change business. While no CDM project has been implemented or is currently being implemented, several DRE projects are being planned and implemented by development agencies, community groups and NGOs. The development of projects is, in most cases, fully funded by international development agencies and NGOs. However, recent events have shown that communities contributing significantly to these projects by providing labour or project inputs. While the government would be keen to see CDM-DRE projects being implemented around the countries, there is no institutional capacity within government itself to support such initiatives. This incapacity translates into a failure to integrate CDM issues within DRE projects.

A previous initiative has helped in building a National Climate Change Committee that include government agencies, other ministries and the private sector. This committee is a strong basis for information sharing but is not mandated to make any decisions because it is not a legal entity. This limitation has made it difficult for the National Committee to be active in pushing climate change initiatives. The National Committee can surely be used, however, to build a local CDM institution and the required capacity.

Sustainable development criteria

Although the country has not developed a Sustainable Development Policy for the CDM as yet, steps have been taken to come up with generic SD indicators and targets that can be used to develop CDM SD criteria. SD performance indicators in the country are divided into three sections namely economic indicators, social indicators and natural resources indicators. The natural resources indicators are further subdivided into smaller and more specific subsections which are: land and soils, vegetation, water, wildlife, minerals, agriculture, energy, transport and tourism.

Economic Indicators: With the base year as 1980, the use of several economic indicators has been proposed: the Real Gross National Product (GNP), the Nominal Gross National Product, the annual growth rate of Nominal GNP and Nominal GNP per capita, Real Gross Domestic Product (GDP), and annual growth rate of Real GDP and Real GDP per capita. The unemployment rate is another useful economic indicator.

Social Indicators: Social indicators have to do with the social welfare of the country. Some of the indicators used include population levels, density and growth rates, and the levels and standards of housing and education, etc. Health is one major cause of concern in the country, hence several indicators are related to health.

Natural Resources Indicators: This set of indicators concerns the protection and conservation of the environment. Some of the issues considered include, pollution, vegetation density and environmental impacts of natural resource extraction.

Given this extensive list of generic SD criteria, we expect that the CDM SD criteria will be derived from them, but with focus on the industrial sector in question.

These SD criteria are consistent with the objectives stated in the Delhi Declaration. The criteria are based on environmental, economic and social development with a special emphasis on poverty reduction. The exploitation of natural resources must be done sustainably to meet economic and social development aspirations of the country, but must also address the mounting levels of poverty. Zimbabwe, just like most countries in the region, has not yet developed CDM SD criteria. This needs to be addressed urgently as there are initiatives currently underway to develop CDM projects in the country. If the CDM SD criteria are not urgently attended to, the country will soon have a situation where proposals to develop CDM projects without relevant assessment criteria.

The Government of India has developed interim SD criteria which emphasize rural development priorities, which state that "The CDM should also be oriented towards improving the quality of life of the very poor from the environmental standpoint."[2] Hopefully similar principles can guide the evolution of Zimbabwe's sustainable development criteria for the CDM.

D. Assessment of ability to support mitigation and adaptation through DRE

Zimbabwe has sufficient technical skills to design and implement DRE projects. The major limitations reside in the administrative structure required for CDM projects and the design of monitoring and verification protocols for very small energy projects. In the absence of special bundling arrangements with sophisticated administrative structures, the potential for DRE as a key mitigation approach will remain unrealized. Industry will dominate the early CDM projects and the benefits to rural communities will remain indirect.

Zimbabwe needs capacity building to support the specific policy objective of designing the CDM and requisite administrative structures to be consistent with national sustainable development priorities, which are largely synonymous with climate change adaptation needs (i.e., agricultural intensification, food security and required strategies for bundling DREs).

Endnotes

1 The National conservation Strategy—Zimbabwe's road to survival, Natural Resources Board, 1987.

2 http://www.envfor.nic.in/cc/cdm/criteria.htm

14. Part II – Synthesis

The various case studies have shown that although the Non-Annex I countries profiled are all eligible to participate in the Clean Development Mechanism, they present markedly different characteristics. These diversities are reflected in their GHG reduction capacities, their reserve of experience in dealing with AIJ and or CDM projects, the state of advancement with regard to setting up of national authorities, the volume of CDM projects being handled, and their capacities for providing support for mitigation and adaptation activities through the execution of decentralized renewable energy projects (DRE). However, it should be admitted that a number of convergent points do exist, mainly in relation to a general commitment towards a progressive engagement with the Clean Development Mechanism. The majority of developing countries are thus actively engaged, to varying degrees, in the CDM learning process.

DRE's viability in terms of mitigation and adaptation activities

All the developing countries recognize that DRE activities constitute a technologically clean option which has the potential of not only contributing to the reduction of GHG emissions, but also of contributing towards sustainable development and poverty reduction in far flung areas.

Project opportunities cover all forms of renewable energy (solar, wind, micro-hydroelectric power, biomass, solid waste, etc.). The existing potential remains largely unexploited, even though the relevant resource assessments for certain countries, such as Bangladesh, are not very reliable. Furthermore, the low consumption of modern energy resources in most developing countries, especially in the rural areas, offers an interesting niche for DRE.

It should be stressed that the countries all have proven experience in the implementation of DRE activities, usually with the assistance of the state, financial partners and with the participation of NGOs and grassroots community groups, and usually with the assistance of various subsidies and facilities. On the other hand, the high transaction costs associated with subsidies, facilities, infrastructures, capacity building, sensitization, follow-up and evaluation, to mention only a few, raise questions about the viability of DRE activities through the CDM. The cost of mitigation per tonne of CO_2, from DRE projects will likely be less competitive than other options.

DRE projects do, however, reinforce the adaptive capacities of local populations, through the development of income generating activities, the reduction of pressure on natural resources and the improvement of living conditions.

Limited experience in managing AIJ and or CDM projects

Countries such as Bangladesh, Senegal and Zimbabwe have very little or no experience with AIJ and/or CDM projects, despite the fact that such countries have already identified existing GHG mitigation potentials in their initial national communications as well as in various CDM capacity-building initiatives. Although this situation could be partly blamed on the lack of understanding of the relevant mechanisms on the part of the principal actors (projects managers and developers), it also exposes the low-level interest shown by development partners and potential investors for these mechanisms. These countries have a preference for capacity-building projects, whose impacts have been rather mixed, owing to their limited duration and the scarce resources available for actual implementation.

Argentina and Brazil, seems to be in relatively better shape, with several confirmed AIJ and CDM projects, most of which have either been submitted for funding or are under implementation. These countries, in line with Bangladesh, Senegal and Zimbabwe, are still in need of capacity-building measures, particularly with respect to supporting DREs within the CDM.

Establishment of Designated National Authorities (DNAs)

The countries are in different stages of establishing their national authorities. Whereas countries like Argentina and Brazil have established an institutional framework for CDM activities, others such as Bangladesh, Senegal and Zimbabwe still make do with the institutional structure set up for the purpose of negotiations and preparation of national communications. Increasingly, public stakeholders have been involved, in conjunction with members of civil society who have similar interests in climate change issues (NGOs, universities and the private sector). However, either the latter do not participate in decision-making processes, or are under-represented.

Furthermore, the ministries responsible for DRE activities do not usually occupy strategic positions within the established institutional frameworks, the structure of which varies from country to country. The focal points of the climate convention (formed from the ministries in charge of the environment in the case of Bangladesh, Senegal and Zimbabwe, and from the ministries responsible for science and technology, in the case of Brazil), play a very significant role in decision-making processes.

The focal points, and in some cases, the permanent CDM secretariats of the different Designated National Authorities, have very limited human and financial resources to undertake their assignments successfully. In this vein, several capacity projects have been undertaken in some of the countries (Bangladesh and Senegal) to assist in the establishment of a Designated National Authority. It should be stressed, however, that technical expertise in managing DRE projects exists but, unfortunately, remains largely unexploited with respect to the institutional framework defined for the CDM.

Sustainable development criteria for the CDM

Although sustainable development is integrated in the development policies of most of the countries concerned, very little progress has been made in defining sustainable development criteria for the CDM. At the same time, there is much debate on how flexible the criteria and indicators should be in order to facilitate investment inflows, thus rendering the CDM more competitive. The emphasis is now being placed on the identification of sustainability indicators and the degree of coherence with development priorities and policies.

In terms of the definition of sustainability criteria and indicators, Brazil is by far the most advanced of the countries concerned. Bangladesh is the recipient of a project to determine sustainable development criteria. It may prove more effective, however, to promote the participation of the civil society, particularly NGOs and grass roots community groups, who are already involved in managing DRE projects.

Poor integration of mitigation and adaptation activities

Adaptation activities in these countries are very rare, despite some discussion in the initial national communications of adaptation strategies. This situation can be explained by the fact that, during the negotiating process, the emphasis was placed squarely on the flexibility mechanisms under the framework of the Kyoto Protocol. Furthermore, the majority of projects initiated give priority to mitigation activities, to the detriment of adaptation activities.

Following the Marrakesh agreements and the creation of a special fund for climate change and for Least Developed Countries, adaptation activities are becoming increasingly important. Countries such as Bangladesh and Senegal are eligible for assistance from funds created for the Least Developed Countries and have already begun preparing their National Adaptation Plans of Action (NAPA). However, none of these countries have formally integrated mitigation and adaptation activities on the institutional level or in their national programs. As for countries which have already set up their Designated National Authorities, only CDM activities have been considered. In Bangladesh and Senegal, the institution set up to prepare the NAPAs has confined itself solely to adaptation activities. Thus, one can only conclude that national institutions still have only a vague perception of the link between mitigation and adaptation, thus creating a potentially uncoordinated role for DRE projects that have strong links to both.

15. Conclusion

The future of international climate policy is uncertain. In the short term, it may continue to be a largely sectoral issue, of interest primarily to energy sector analysts and meteorological service bureaucrats. As the developing world has forcefully asserted, however, climate change is fundamentally a sustainable development issue, one with long-term implications for the world's most vulnerable communities. Meeting the sustainable livelihood needs of the world's poor, while simultaneously reducing greenhouse gas emissions, will be one of the most important challenges of the coming decades.

Any future climate change mitigation regime must contend with two related greenhouse gas (GHG) emission issues: deforestation and rural energy deprivation. Unabated deforestation and rural energy deprivation—at once symptoms and causes of chronic rural poverty—will frustrate attempts at comprehensive GHG emissions mitigation, and will only exacerbate the climate change vulnerability of the poor. The scale of the issue should not be under-estimated—land use change (mostly deforestation in tropical regions) now accounts for a quarter of all GHG emissions. 2.4 billion mostly rural people have no access to electricity, a condition that undermines their well-being and perpetuates a vicious cycle of agro-ecosystem breakdown that exacerbates critical climate change vulnerabilities like food and water security. In this context, decentralized renewable energy (DRE) is a logical response, as it addresses critical climate change adaptation needs while remaining entirely consistent with fundamental United Nations Framework Convention on Climate Change (UNFCCC) mitigation objectives.

Seeing the Light has presented voices from the South and has described the experience of five countries with decentralized renewable energy and their capacity to support and develop DRE, including through climate change financial mechanisms, notably the Clean Development Mechanism (CDM). What emerges from this survey, is that the linkages between mitigation and adaptation issues around DRE are indeed real, and are already an implicit foundation of national energy policies that recognize the poverty alleviation and environmental sustainability co-benefits of rural energy access. We believe that the central hypothesis of the book—that DRE is both a mitigative and adaptive response to climate change and represents an important new focus for integrated climate policy—is clearly demonstrated in striking examples from all five countries.

In addition to being highly vulnerable to the negative impacts of climate change, many developing countries (including those surveyed in *Seeing the Light*) are simultaneously undergoing power sector reform, a process designed to introduce new regulatory models, increased competition and private ownership—and often driven by the conditionalities package imposed by the World Bank and other foreign donors. Power sector reform is not fundamentally incompatible with the mitigation-adaptation synergies associated with DREs—in fact reform can create DRE market opportunities that would never have otherwise existed. If, however, power sector reform proceeds without a strong vision of how the carbon market and DRE mitigation-adaptation synergies can be harnessed, a major sustainable development opportunity will be lost. Unfortunately, what this book also reveals is that the policy cohesion and capacity to link energy access in vulnerable communities to power sector reform and carbon financing opportunities is, at best, tentative and, at worst, completely uncoordinated.

The developed world should not squander this opportunity to align international climate policy with the large mitigation opportunities created by the forces reshaping energy markets in the South, with the sustainable development aspirations of South. The Global Village Energy Partnership (http://www.gvep.org) and the Global Environment Facility (http://www.undp.org/gef) are important multilateral capacity-building and financing efforts, but as the Argentine country study shows, the available resources frequently pale compared to the scale of the issues.

Although the power sector reform process in Argentina created DRE markets, the authors are clear that, left to their own devices, private power sector players will attempt to maximize efficiency and preferentially serve urban consumers. The Argentine government initially contemplated a US$300 million rural electrification investment to correct for these market failures. A much scaled-down version (PERMER) was eventually funded by the World Bank-GEF at one-tenth the original project size. The PERMER case study featured here also reflects a fundamental characteristic observed throughout this book; the communities suffering most from energy deprivation are also those most vulnerable to climate change. Successful DRE interventions require an integrated rural development approach that builds the capacity to transform energy access into livelihood opportunities and increased adaptive capacity. Although the Argentine government has demonstrated some receptivity towards the CDM and the small-scale modalities and procedures that can facilitate DRE, there is as yet no ministerial-level integration of DRE policies within the CDM governance structure, nor is there any general integration of CDM policies within national sustainable development policy.

In Bangladesh, one of the countries perceived to be the most vulnerable to climate change, the mitigation-nexus is particularly striking, as the unmanaged use of biofuels exacerbates land degradation and intensifies a critical climate change vulnerability. Furthermore, another major climate change vulnerability in Bangladesh is food security, yet a large amount of this country's agricultural production spoils every year because no electricity is available for rural cold storage. Household electrification also has an enormous uplifting effect on adaptive capacity generally—higher incomes, higher security, increased working hours, and more study time all have profoundly positive impacts on human well-being.

The prospects for integrating DRE into Bangladesh's climate change and CDM strategies are actually reasonably positive. Although no GHG mitigation study in Bangladesh has dealt comprehensively with DRE, Bangladesh's National Communications (to the UNFCCC) emphasized a role for DRE in reducing deforestation. Unfortunately, there is no indication that energy deprivation will be considered a key vulnerability, or that DRE will be promoted as an adaptation strategy in the National Adaptation Programs of Action process now underway. Bangladeshi CDM sustainable development criteria are expected to deal with the most significant environmental (and climate change vulnerability) issues, such as land degradation, hence adaptation issues will be an implicit consideration. A key role for DRE, though, is not yet clear. The ministry responsible for DRE is currently not represented within Bangladesh's Designated National Authority (DNA).

Brazil is rather unlike the other countries surveyed having, for example, a well-developed bioenergy industry and plans for further expansion. Although the lack of vulnerability analyses for Brazil is a serious concern, Brazil is like the other countries in some other respects: the communities that appear to be most vulnerable to climate change are remote, the least-developed and suffer the greatest energy deprivation. As the case study describes, there is considerable potential for serving these remote communities with a familiar technology—biodiesel-based electrification—while simultaneously reducing key climate change vulnerabilities by targeting degraded land for biodiesel feedstock production. Brazil's political efforts to enshrine the universality of key human rights and services should make an evolution towards DRE-based energy services for remote communities inevitable. The near-term likelihood, however, that the CDM market will facilitate expansion of these services is low as Brazil is still struggling to determine whether its CDM sustainable development criteria should encourage the most investment or explicitly favour DRE.

Of the countries surveyed, Senegal is among the most vulnerable to climate change, located in the fragile Sudano-Sahelian zone of Africa. Senegal is also perhaps the best example of existing energy policy already based around mitigation-adaptation synergies. The potential for DRE services to contribute to poverty alleviation and improved natural resources stewardship is well understood by Senegalese policy-makers and clearly outlined in national policy. The case studies from Senegal illustrate the benefits of decentralized electricity provision—immediately reduced exposure to critical climate vulnerabilities like drought and desertification. The challenge in Senegal appears to be building the necessary level of policy cohesion around climate change issues to tackle vulnerabilities and mitigation opportunities in a coordinated fashion. Like Bangladesh, Senegal's first National Communication emphasized DRE, and its Poverty Reduction Strategy Paper (a prerequisite for World Bank loans) recognized energy as a cross-cutting issue. Senegal still lacks, however, a comprehensive strategy for integrating climate change issues with its national sustainable development policies.

The Zimbabwean country study reveals many similarities to Senegal; in both countries the critical climate change issues are food and water security. Like Senegal, Zimbabwe's national energy policy implicitly recognizes the mitigation-adaptation nexus; rural energy provision is regarded as essential for livelihood security and the wind energy case studies are apt illustrations. Zimbabwe's capacity to embrace the CDM to support DRE dissemination is less clarified, however. Interest in the CDM in Zimbabwe has thus far been limited to conventional energy and industrial investments that would upgrade the existing capital stock, reflecting a conventional top-down development model wherein sustainable development considerations are usually relegated to peripheral status. Without irony, the author notes that national climate policy coordination is fragmented in any case as the government is generally pre-occupied by crisis management issues such as "grinding poverty, droughts and floods"—foreboding indications of high climate vulnerability, and the very issues that DRE would address (recall Figure 1.12). More positively, both African countries surveyed demonstrate the capacity to deliver a high-level of local technical DRE content, which undoubtedly greatly aided Senegal's photovoltaic program and the Zimbabwean wind program.

So, where do we stand? The existing mechanism specifically designed to facilitate technology transfer and sustainable development in the South, the CDM, does not appear to be promoting DRE to any great degree—despite wide recognition within national governments that renewable energy technologies are entirely practical for delivering energy services to impoverished regions. CDM host countries, such as those surveyed here, cannot be faulted for not aligning the CDM with their DRE and rural development programs as they perceive the CDM as a fixed-sum game; if they choose to host higher-cost DRE projects, they will be passed over in favour of lower-cost projects elsewhere.

For a climate policy orientation that seeks out mitigation-adaptation synergies, with DRE as a centrepiece strategy, the North must lead and more forcefully recognize the South's sustainable development aspirations. The simplified modalities and procedures available under the CDM to assist decentralized rural projects proponents are appropriate, but simply insufficient to drive the World Summit on Sustainable Development (WSSD) agenda and the Millennium Development Goals forward. Engaging the South through mitigation-adaptation synergies would demonstrate a commitment to development that has long been promised, but not consistently regarded by the North as being in its immediate interest. The governance of the global commons changes this dynamic.

Steps towards a deeper integration of sustainable development within climate policy through mitigation-adaptation synergies—and specifically DRE—can begin now if supported by greater coordination, capacity building and funding commitments from the North. Recommended steps include:

- Vulnerability studies using regionally-downscaled climate models need to be completed throughout the developing world. Since climate change vulnerability, particularly for the poor, is manifest as the loss of critical ecosystem provisioning and regulating functions, the Millennium Ecosystem Assessment could serve as an appropriate global coordinating agency for such studies.
- Future National Communications required of Parties to the UNFCCC should include mapping assessments of energy use and deprivation as indicators of vulnerability.
- National Adaptation Programs of Action should include analyses of energy use, energy deprivation and the role of energy services in adaptation.
- DNA capacity-building efforts should encourage representation from ministries responsible for the energy, agriculture, forestry and environment sectors, and should encourage coordination with national sustainable development policies.
- Capacity-building is needed among the NGOs, universities and other civil society partners that continue to be the strongest DRE supporters in the South.
- Portfolio standards by Annex-I countries on CDM purchases should be explored. Governments, for example, could require that a fixed percentage of the entire portfolio of CDM credits used to meet its emissions targets come from DRE or community-managed sequestration projects with high adaptation benefits.

Conclusion

- Commitments should be made to sustained research and development of DRE technologies appropriate to the basic livelihood needs in developing countries.
- Policy cohesion between power sector reform and climate change strategies should be strengthened, particularly through DNA capacity-building. Power sector reform creates opportunities for DRE, carbon financing and more environmentally sustainable energy sector options. Thus, power sector reform and DNA capacity-building to support decentralized renewable energy are two sides of the same coin and deserve far greater integration than has as yet been contemplated.

Fulfilling these recommendations will not be easy, but the rewards from the North and South coming together over this otherwise divisive issue are so great, that concerted effort by developing and developed countries alike to achieve these potential synergies is justified and urgent. Not only will these efforts build good faith as the global community moves forward within the international negotiations, it will assist in addressing the wider responsibility of the global community—to meet the long-term sustainable livelihood needs of its poorest and most vulnerable members.

From *Seeing the Light…*

"The central theme of this book is that well-designed decentralized renewable energy projects are in fact a mitigative and an adaptive response to climate change. DREs address core sustainable development priorities and build adaptive capacity to climate change, without increasing GHG emissions. Building coherent climate policy around the DRE option is a win-win opportunity that overcomes the policy divide by addressing the South's adaptation needs and the North's mitigation priorities. In supporting strong DRE-based climate policy, the North can build the good faith necessary to meaningfully engage the South in a post-Kyoto phase of climate negotiations."

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