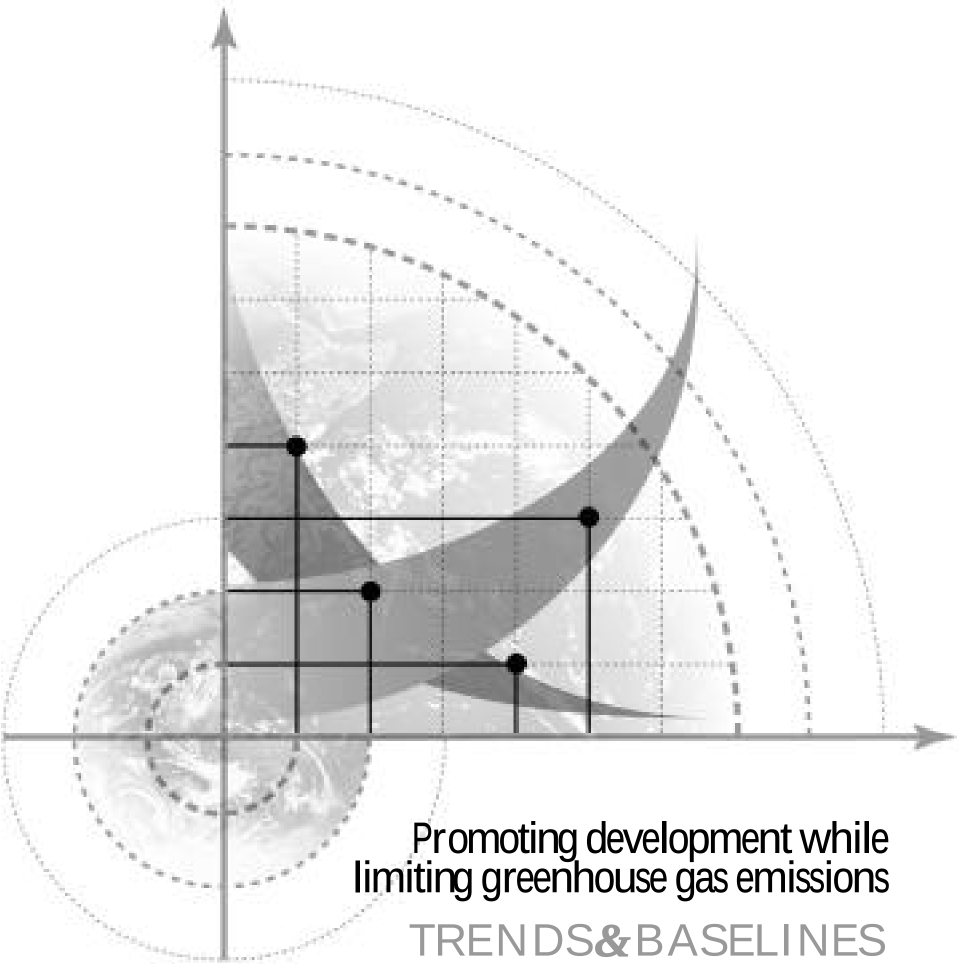


Promoting development while limiting greenhouse gas emissions

TRENDS & BASELINES

Editors

José Goldemberg
Walter Reid

Contributors

Weber Amaral	Nick Eyre
Indira López-Bassols	Axel Michaelowa
Kevin A. Baumert	Rajendra K. Pachauri
Juan Carlos Belausteguigoitia	Èneas Salati
Ogunlade R. Davidson	Sudhir Sharma
Michael Dutschke	Carlos Enrique Suárez
Angelo Augusto dos Santos	ZhongXiang Zhang

United Nations Development Programme
World Resources Institute

United Nations Publications

UN Sales No. E.99.III.B.32
ISBN: 92-1-126112-0

1 United Nations Plaza
New York, NY 10017 USA

Promoting development while limiting greenhouse gas emissions

TRENDS & BASELINES

Table of Contents

vii Notes on Contributors

ix Acknowledgements

xi Foreword
James Gustave Speth, Administrator, UNDP
Jonathan Lash, President, World Resources Institute

OVERVIEW

1 Greenhouse Gas Emissions and Development: A Review of Lessons Learned
José Goldemberg, Walter Reid

TRENDS: LATIN AMERICA

15 Chapter 1
Argentina's Ongoing Efforts to Lower Greenhouse Gas Emissions
Carlos Enrique Suárez

25 Chapter 2
Mexico's Policies and Programmes that Affect Climate Change
Juan Carlos Belausteguigoitia, Indira López-Bassols

TRENDS: ASIA

45 Chapter 3
Is China Taking Actions to Limit its Greenhouse Gas Emissions? Past Evidence and Future Prospects
ZhongXiang Zhang

59
Chapter 4
India's Achievements in Energy Efficiency
and Reducing CO_2 Emissions
Rajendra K. Pachauri, Sudhir Sharma

TRENDS: AFRICA

75
Chapter 5
Energy Initiatives in Africa for Cleaner Development
Ogunlade R. Davidson

TRENDS: AN ANNEX I COUNTRY EXAMPLE

85
Chapter 6
Carbon Dioxide Emission Trends
from the United Kingdom
Nick Eyre

A SECTORAL VIEW: BRAZIL

101
Chapter 7
Investing in Carbon Storage:
A Review of Brazilian Forest Projects
Èneas Salati, Weber Amaral, Angelo Augusto dos Santos

METHODOGICAL ISSUES

115
Chapter 8
Economic and Political Aspects
of Baselines in the CDM Context
Axel Michaelowa, Michael Dutschke

135
Chapter 9
Understanding Additionality
Kevin A. Baumert

147
Glossary of Abbreviations

Notes on Contributors

EDITORS

Walter Reid works independently on environment and development policy issues internationally, and is a Visiting Fellow at WRI, where he has also served as Vice President for Program and as Senior Associate in the Biological Resource Program. For six years, Dr. Reid was a Gilbert White Fellow with Resources for the Future in Washington, D.C. He has researched and written widely in the fields of biodiversity conservation, climate change, energy policy, sustainable agriculture, and biotechnology. E-mail: waltreid@ibm.net

José Goldemberg is the former Rector and Full Professor of the University of São Paulo. He has served as the President of the Brazilian Association for the Advancement of Science and as Brazil's Secretary of Science and Technology and as Secretary of the Environment and Minister of Education. He has written widely about nuclear physics, environment and energy. E-mail: goldemb@iee.usp.br

CONTRIBUTORS

Weber A. N. Amaral is a professor at the University of São Paulo, Forest Sciences Department, Piracicaba, SP, Brazil. E-mail: wanamara@carpa.ciagri.usp.br

Angelo Augusto dos Santos is the Coordinator for External Affairs at the Brazilian Foundation for Sustainable Development, Rio de Janeiro, Brazil. E-mail: ursao@ax.apc.org.br

Kevin Baumert is a research analyst in the climate, energy and pollution programme of WRI, Washington, D.C. His research focusses on the Kyoto Protocol and climate change policy instruments, including emissions trading and the Clean Development Mechanism. E-mail: kbaumert@wri.org

Juan Carlos Belausteguigoitia is the Under-Secretary of Planning at the Ministry of the Environment and Professor of Economics at the Autonomous Technological Institute of Mexico (ITAM). E-mail: jbelauste@buzon.semarnap.gob.mx.an

Ogunlade R. Davidson is the Dean of Engineering at the University of Sierra Leone. He is currently a visiting professor at the United Nations Environment Programme Centre at RISØ Laboratories, Roskilde, Denmark. E-mail: ogunlade.davidson@risoe.dk

Michael Dutschke is a researcher on climate policy at the Hamburg Institute for Economic Research (HWWA), Hamburg, Germany, with a special focus on North-South relations. E-mail: dutschke@hwwa.de

Nick Eyre is the head of Policy Development at the Energy Saving Trust. He has worked as a consultant and researcher on environmental and energy policy and on a wide range of projects for international organisations, UK Government departments, major energy companies and NGOs. E-mail: nick@eyrenenv.demon.co.uk

Indira López-Bassols is a reseacher at the National Commission for the Knowledge and Use of Biodiversity and an evironmental consultant in Mexico. E-mail: ilopez@xolo.conabio.gob.mx

Axel Michaelowa is the head of climate policy research at HWWA, Hamburg, Germany. Since 1994, he has focused on flexibility mechanisms and has been an observer of the FCCC process since COP-1. E-mail: michaelo@easynet.fr

Rajendra K. Pachauri is the Director of the Tata Energy Research Institute (TERI) in New Delhi. Since 1994, he has served the UNDP Administrator as adviser for Energy and Sustainable Management of Natural Resources. He is also vice-chairman of the IPCC and the author of 21 books. E-mail: pachauri@teri.res.in

Carlos E. Suárez is the President of the Bariloche Foundation, a private non-profit research and postgraduate centre in Argentina. He has researched and written widely on energy and environment since 1963. He serves on the scientific advisory board of the RISØ Research Centre in Denmark and the editorial board of several international publications. E-mail: fb@bariloche.com.ar

Sudhir Sharma is a research associate at TERI’s Center for Global Environment Research. He has worked on a number of climate change projects, including the Asia Least Cost Greenhouse Gas Abatement Study (ALGAS) in India. E-mail: sudhirs@teri.res.in

Èneas Salati is the Technical Director at the Brazilian Foundation for Sustainable Development, Rio de Janeiro, Brazil. E-mail: fbds@ax.apc.org.br

ZhongXiang Zhang has joint appointments at the Faculty of Economics and the Faculty of Law, University of Groningen, the Netherlands, and the Chinese Academy of Social Sciences in Beijing. He has published articles in the fields of energy and environmental economics, trade and the environment, public finance, and economic modeling. E-mail: Z.X.Zhang@rechten.rug.nl

Acknowledgements

This report is the result of collaboration between the United Nations Development Programme (UNDP) and the World Resources Institute (WRI) and expands on the 1997 WRI Climate Note article “Are Developing Countries Already Doing as Much as Industrialised Countries to Slow Climate Change?” The project was carried out under Professor Thomas B. Johansson, Director of UNDP’s Energy and Atmosphere Programme (EAP), in the Sustainable Energy and Environment Division (SEED), and Dr. Nancy Kete, Director of Global Climate for WRI.

UNDP and WRI are deeply grateful to the extensive group of experts involved in completing this project. Above all, they are greatly indebted to Professor José Goldemberg and Dr. Walter Reid, the editors of the publication, for their leadership and commitment to the project. Many thanks are also extended to the authors of the report, all of whom were committed to the ideas behind the report as well to producing high quality contributions.

The report benefited from the technical editing, patience and support provided by Janet Jensen. Maureen Lynch of the UNDP Division of Public Affairs (DPA) provided assistance throughout the production process. Credit for the design of the publication goes to Julia Ptasznik, Associated Print Productions. Recognition is extended to Caitlin Allen-Sanchez and Annie Roncerel, UNDP/EAP, for managing the project and following through on the myriad details that went into its drafting, review, editing and production.

Foreword

James Gustave Speth
Administrator, UNDP

Jonathan Lash
President
World Resources Institute

In 1997, Dr. Walt Reid and Professor José Goldemberg produced a *Climate Note* for the World Resources Institute, in which they demonstrated that, contrary to common perceptions, many developing countries were already contributing significantly to climate change mitigation. The Reid-Goldemberg analysis estimated that since the signing of the 1992 Framework Convention on Climate Change, developing country policies and measures had created more carbon emissions savings than had been achieved in the United States and other industrialised countries. This was a startling finding from a modest effort, and the report attracted considerable attention at Kyoto, among negotiators and observers to the Conference of Parties to the Climate Convention.

This publication updates and expands on the previous Reid-Goldemberg analysis, calling upon the expertise of country experts to document the emissions impacts of various macro-economic, structural and sector policies in Argentina, Brazil, China, India and Mexico, as well as throughout Africa. A case study of the United Kingdom provides a good point of comparison. These five large developing countries account for approximately 23% of greenhouse gas (GHG) emissions worldwide, and approximately two-thirds of emissions from non-Annex I countries, and the UK is one of the few Annex I countries that has kept its emissions from increasing above the 1990 levels.

The country studies in this report reinforce the findings of the Reid-Goldemberg *Climate Note*, namely that the case-study countries are implementing policies and measures that reduce the rate of growth of greenhouse gas emissions. In all of these countries, including the United Kingdom, the documented carbon savings actions were motivated less by concern for climate protection than because of the social and economic benefits they provided. This new report helps to identify a set of policies and measures being instituted for development purposes that can also provide ancillary benefits for climate protection. These are the most promising areas where developing countries can contribute further to solving the climate challenge. The political commitment required to implement the energy sector policies has been substantial, more than has been evident in some major industrialised countries.

The case studies not only document the carbon impacts of fiscal, structural and energy sector policies. They provide a good starting point for consideration of the highly complicated, and potentially contentious, baseline issue. In principle, a variety of different baselines — national, sector, or project-specific — could be useful in the context of the climate convention and Kyoto Protocol. But baselines are always problematic. For example, the country studies examined in this volume illustrate an important conclusion regarding national baselines. A national baseline constructed from net carbon emissions, that is, in tonnes per year, is likely to be highly subject to changes in GDP growth rates due either to national policy changes or, as the current financial crisis shows, international forces seemingly outside of anyone's direct control. On the other hand, baselines constructed using carbon emissions per unit GDP, or the carbon intensity of the energy mix, tend to be less variable and less subject to factors beyond the control of policymakers, and are thus a better indicator of whether a country is continuing to make progress in de-coupling emissions from economic development. Given fears that a cap on emissions might become a cap on economic growth, for large, rapidly growing developing countries, for the next decade at least, a sustained reduction in carbon intensity is a good indicator of a country's contribution to avoiding or slowing climate change.

Since Kyoto, developing and industrialised countries alike have exhibited an intense interest in getting the Clean Development Mechanism — a new instrument first defined in the Kyoto Protocol — operational as early as possible. This collective interest in finding new ways to finance sustainable development and reduce the growth in GHG emissions is extremely promising. The volume includes two papers specifically focussed on baselines and additionality, issues central to the Clean Development Mechanism.

Developing countries are far from being passive spectators in the drive to protect the global climate system. Many are reducing their GHG emissions below the levels that would occur otherwise. The trends, policies and measures behind these improvements have required leadership and entailed political cost. These need to be recognised if we are collectively to meet the challenge of reducing the threat of climate change while increasing the sustainable human development opportunities for all.

James Gustave Speth
United Nations
Development Programme

Jonathan Lash
World Resources Institute

Greenhouse gas emissions and development: a review of lessons learned

José Goldemberg
University of São Paulo
São Paulo, Brazil

Walter Reid
World Resources Institute
Washington, DC

Significant growth in energy consumption in developing nations is essential and inevitable in the coming decades. Increasing energy use will help to fuel needed economic development in these nations. Rising incomes and growing populations will, in turn, elevate energy demands. But as energy consumption in developing nations grows, so too will emissions of greenhouse gases (GHGs); with time, these emissions will become increasingly significant contributors to climate change. Consequently, a major climate policy challenge is to devise a means to reduce the *rate* of growth in GHG emissions without impeding these nations' development.

Compared to the industrialised nations, developing countries have contributed little to current concentrations of GHGs in the atmosphere. Their national priorities are economic development and alleviation of poverty. But these priorities by no means preclude actions that can help to reduce the risk of climate change. Specifically, where the rate of growth in carbon emissions can be reduced through measures that do not impede — or may even enhance — development prospects, promising opportunities exist for developing countries to contribute to solving the climate challenge.

In fact, developing countries are already contributing to climate mitigation as they pursue economic development, and they will continue to do so as they achieve their development objectives. Recent reviews by Capoor *et al.* (1996) and Reid and Goldemberg (1997) have documented significant steps that are being taken by developing countries to reduce rates of growth in carbon emissions. Indeed, since the 1992 signing of the United Nations Framework Convention on Climate Change (UNFCCC), carbon emission savings in developing countries may be greater than those attained by industrialised countries (Reid and Goldemberg, 1997). Typically, the policies and measures that reduced rates of growth of carbon emissions were not motivated primarily out of concern for climate protection, but rather to achieve other social and economic goals. Regardless of the motivation, however, these policies and projects demonstrate the types of actions that could be intensified through international or national efforts, because they provide clear development

TABLE 1: Flexibility Mechanisms in the Kyoto Protocol

Type	Article	Requires project	Restricted to Annex B countries	Requires establishment of baseline
Bubbles	4	No	Yes	No
Joint Implementation	6	Yes	Yes	Yes
International Emissions Trading	17	No	Yes	No
Banking	3.13	No	Yes	No
Adjustment of Sinks	3.4	No	Yes	No
Base year for HFCs, PFCs, SFs, SF_6	3.8	No	Yes	No
CDM*	12	Yes	No	Yes

*A proposal to replace "projects" by "programmes and policies" was presented in Kyoto and rejected.

benefits while contributing significantly to the climate challenge ahead.

The primary objective of this report is to identify the types of actions and projects that offer the most promising opportunities for accelerating human development, particularly in developing countries, while reducing rates of growth of GHG emissions. The core of the report is a set of seven case studies: Argentina, Mexico, China, India, Africa, the United Kingdom, and Brazil. The case studies explore recent patterns of energy development and explain how various policies and projects have influenced GHG emissions. The five large developing countries examined in this report (Argentina, Mexico, China, India, and Brazil) currently account for approximately 23% of GHG emissions worldwide, and approximately two-thirds of emissions from non–Annex I countries (WRI, 1998). A review of energy trends across Africa — which has low levels of GHG emissions, but considerable potential both for growth and for avoided future emissions — is included as well. Evidence presented indicates that it is indeed possible to combine development and GHG mitigation in a significant way. This volume also includes a chapter discussing the UK's recent energy trends. Carbon emissions in the UK have declined significantly since 1990, and such declines in the carbon intensity of an industrialised country are instructive.

The information in these country case studies is also relevant to deliberations on the design of the Clean Development Mechanism (CDM). One significant achievement of the Kyoto Protocol, in addition to the establishment of binding targets for Annex B countries, was the incorporation of various flexibility mechanisms that, in theory, will reduce the costs to Annex B countries of achieving their quantified emission limitation and reduction commitments (QELRCs) (Table 1). As Table 1 indicates, among the Protocol's "flexibility mechanisms" only the CDM was specifically designed to include non–Annex B countries.

The CDM is intended to promote "win-win" actions in developing countries — that is, actions, like many described in the case studies, that enhance development prospects while reducing growth in GHG emissions. By providing what should be relatively low cost options for such reductions, the CDM could substantially aid global efforts to reduce the rate of increase of GHG emissions. At the same time, the CDM should aid development prospects of developing countries by stimulating technological "leapfrogging" and generating new investments.

The case studies in this volume thus shed light on the nature of projects that could be suitable for inclusion in the CDM and complement the discussion of this novel mechanism (Goldemberg, 1998). They also provide a context for one of the most challenging dimensions of CDM design — the determination of the "baseline" for measuring GHG emission savings. Two additional chapters in the volume, by Michaelowa and Dutschke (Chapter 8) and Baumert (Chapter 9), explore this issue in greater depth.

The seven case studies illustrate a number of consistent patterns in energy development that have been the subject of extensive analysis (Reddy et al., 1997; Goldemberg et al., 1988). Some of the basic patterns are the following:

Carbon Emissions in all Countries Have Grown Significantly with Economic Development.

Both population growth and economic growth are associated with increased energy demand. Because energy supply in most countries is largely based on fossil fuels, carbon emissions tend to grow rapidly with development, particularly among countries with relatively low levels of per capita income. For example, among low-income economies (excluding China), GDP grew at a rate of 2.8% per year between 1980 and 1994, while commercial energy consumption grew at a much higher rate — 4.7% per year, as Table 2 shows.

The reasons for this are straightforward — the energy demands of industrial economies are far greater than those of agricultural economies. Moreover, with increasing per capita income, household energy use grows because of the increased number of appliances. Energy consumption for transportation grows as the per capita ownership of private vehicles increases. And commercial energy sources substitute for fuels, such as fuel wood, used by poorer families.

Among high-income countries, however, growth in energy consumption becomes increasingly "decoupled" from growth in GDP for a number of reasons. These economies often experience shifts from energy-intensive industrial sectors to less intensive service sectors. Moreover, the level of energy use in certain sectors, such as households, becomes saturated as most consumers reach income levels at which further growth in the consumption of energy-intensive appliances slows. Finally, technological advances regularly increase energy efficiency, holding down growth in energy demand even with growing economic activity. As a result of these factors, some OECD countries have exhibited stable or declining levels of carbon emissions in recent years, even before beginning to implement measures under the UNFCCC.

Commercial Energy Intensity of all Countries Grows at Low Levels of Per Capita Income but Ultimately Begins to Decline at Higher Income Levels.

The "energy intensity" of a country is defined as the ratio of national energy consumption (E) to gross domestic product, or E/GDP. Energy intensity is a constant if and only if the structure of the economy and energy mix and the efficiency of energy use remain constant. Measures of energy intensity have some attractive features: while per capita energy use and per capita GDP vary by more than a factor of 10 among countries, energy intensity does not change by more than a factor of 2 because of the common characteristics of the energy systems in different countries.

Data collected for more than a century in some industrialised countries, such as the UK, US, Germany, France, and Japan, permit assessment of

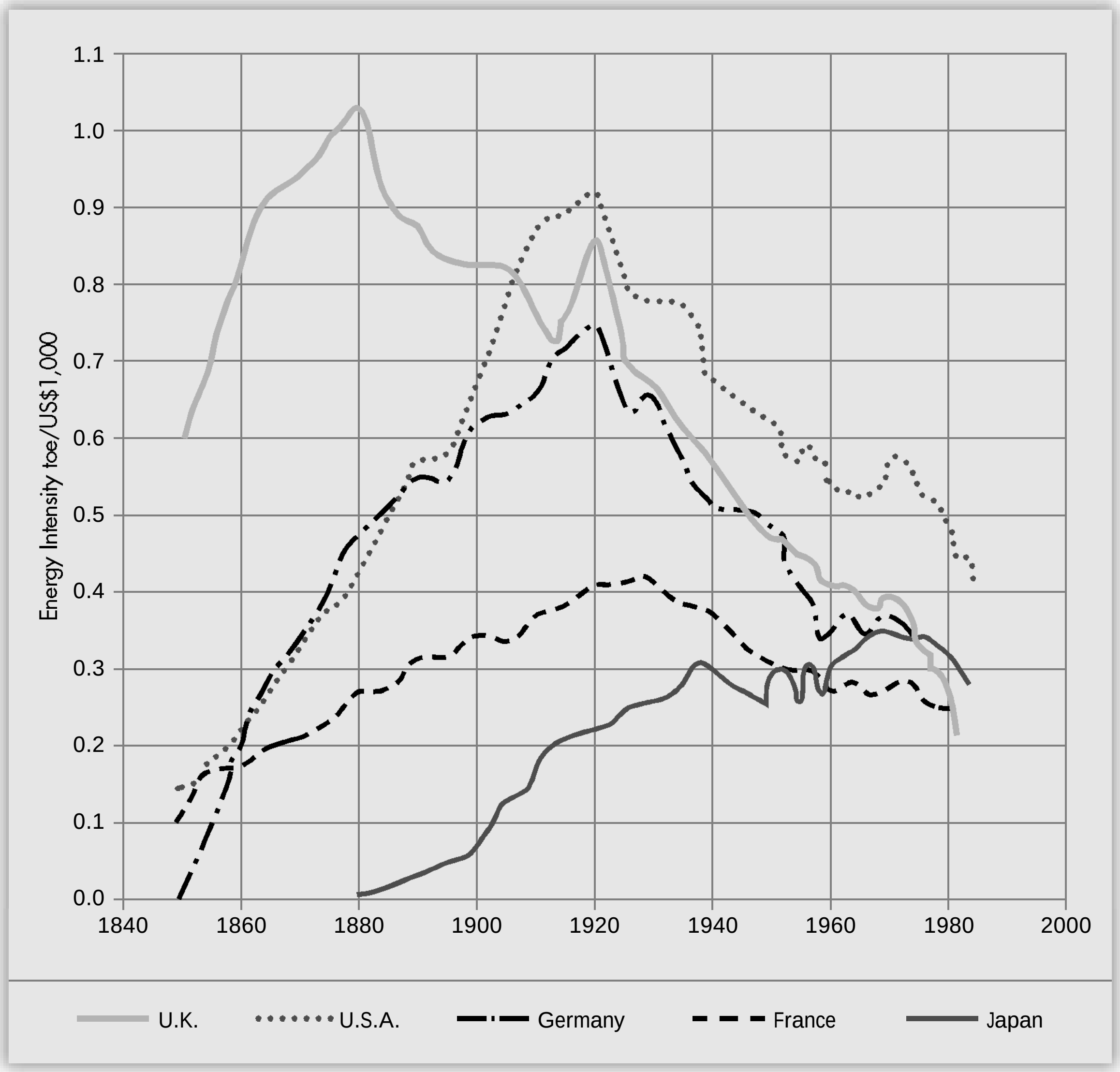
TABLE 2: Growth Rates of GDP and Energy Consumption and Income Elasticity of Energy Consumption in Different Economies, 1980-1994. Growth of energy consumption exceeds rate of GDP growth in low-income countries, but is less than the GDP growth rate in high-income economies.

	Annual growth of GDP (%)	Annual growth of energy consumption (%)
Low-income economies*	2.8	4.7
Upper-middle-income economies	2.5	3.9
High-income economies	2.8	1.1

*Excluding China

Source: Zhang, this volume.

FIGURE 1: Energy Intensity of Industrialised Countries (only commerical energy)



Source: Martin, J.M., L'intensité énergetique de l'activité économique dans les pays industrialisés: les évolutions de très longues périodes livrent – elles des enseignements utiles? Economies et Sociétés – Cahiers de l'ISMEA, 32(4), pp. 9-27, 1988.

long-term trends in energy intensity (Figure 1). Thus, it is well known that the energy intensity in these countries increased as the infrastructure and heavy industry developed, peaked, and then began a steady decline. Latecomers in the industrialisation process, such as Japan, peaked at lower energy intensities than their predecessors, indicating early adoption of innovative and modern, more energy-efficient industrial processes and technologies. This is called "technological leapfrogging," or the "follower advantage" in the language of economists.

Developing countries are clearly in this category and their energy intensities are comparable to industrialised countries not only because of modernisation of their economies, but also because they are using renewable energies such as biomass with better technologies than in the past in industrialised countries (Nielsson, 1993).

The energy-intensity trend in a country reflects much more than just specific policies directly influencing energy use. The decline in economy-wide and sector energy intensities among high-income economies is explained by a number of factors:

1. A structural shift in the economy from dominance by sectors with relatively high

energy intensity to dominance by sectors with relatively low energy intensity

2. A shift in the energy mix from fuels used with lower efficiencies (such as coal) to fuels with higher efficiencies (natural gas)

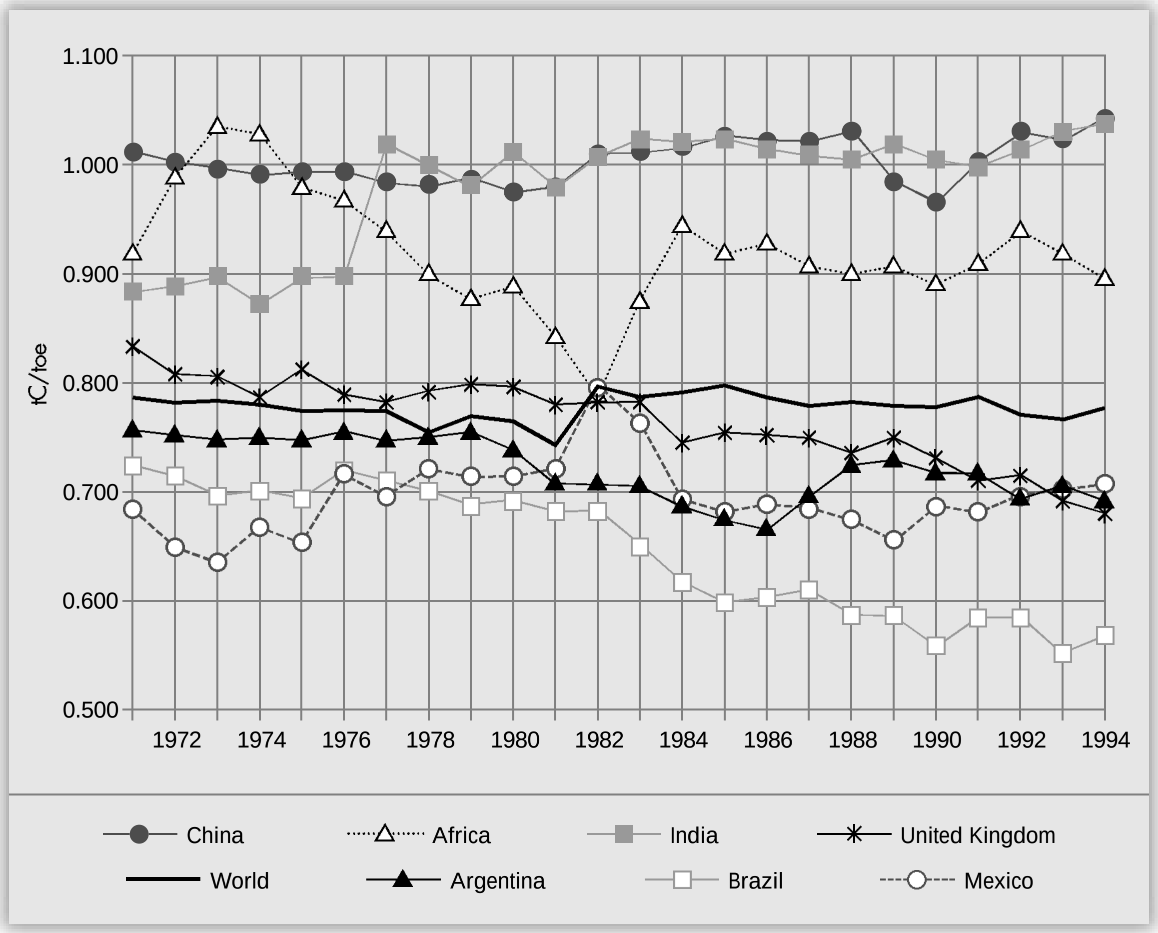
3. Steady improvement in the efficiency of energy production and end-use technologies

4. Policies that promote more efficient energy use, such as increased fuel prices, vehicle emissions standards, and renewable energy subsidies

Although energy intensity is a useful indicator of energy trends, it has one important drawback in its applicability to the issue of climate change: two countries with the same GDP and same energy intensity could differ dramatically in their emissions of GHGs if their energy sources differed in carbon content. Countries such as Brazil and France, for example, which derive significant energy from non-fossil fuels (hydropower and nuclear energy), emit far less carbon into the atmosphere than other nations with comparable energy intensities and GDP. For this reason, measures of "carbon intensity of the economy" (C/GDP), the quantity of carbon emissions per unit of GDP, are better indicators of the relative level of GHG emissions from commercial energy sources in different countries. Brazil and France, for example, would have low carbon intensities compared to countries like China and India, where coal dominates energy use.

Another useful measure is the carbon intensity of the energy supply, or C/E, which specifically reflects changes in the commercial fuel mix of a country (Figure 2). The carbon intensity of the economy is equal to the carbon intensity of the

FIGURE 2: Trends in Carbon Intensity in Selected Countries, 1971-1994



Source: WEC/IIASA, 1995; O. Mielnik and J. Goldemberg (in press).

energy supply times the energy intensity of GDP, or

$$C/GDP = (C/E) \times (E/GDP)$$

thus

$$\frac{\Delta (C/GDP)}{(C/GDP)} = \frac{\Delta (C/E)}{(C/E)} + \frac{\Delta (E/GDP)}{(E/GDP)}$$

or

$$Y = \frac{\Delta (C/E)}{(C/E)} = \frac{\Delta (C/GDP)}{(C/GDP)} - \frac{\Delta (E/GDP)}{(E/GDP)}$$

= the slope of the carbon intensity of the energy supply.

If the energy mix of a country remains constant over time, then $Y = 0$. If there is a switch to coal, then $Y > 0$, and a "carbonisation" of the economy occurs, as is shown in the case of India (Figure 2). If there is a switch away from coal, then $Y < 0$, and a "decarbonisation" of the economy occurs, as in the case of Brazil (also shown in Figure 2).

In recent years, both China and India have been "carbonising economies" ($Y > 0$), although the reliability of available data leaves much to be desired. This is probably due to a switch from non-commercial energy sources — particularly biomass — to coal. Gains in efficiency in the use of coal in China have not been enough to offset an increase in the "carbonisation index."

CASE STUDY FINDINGS

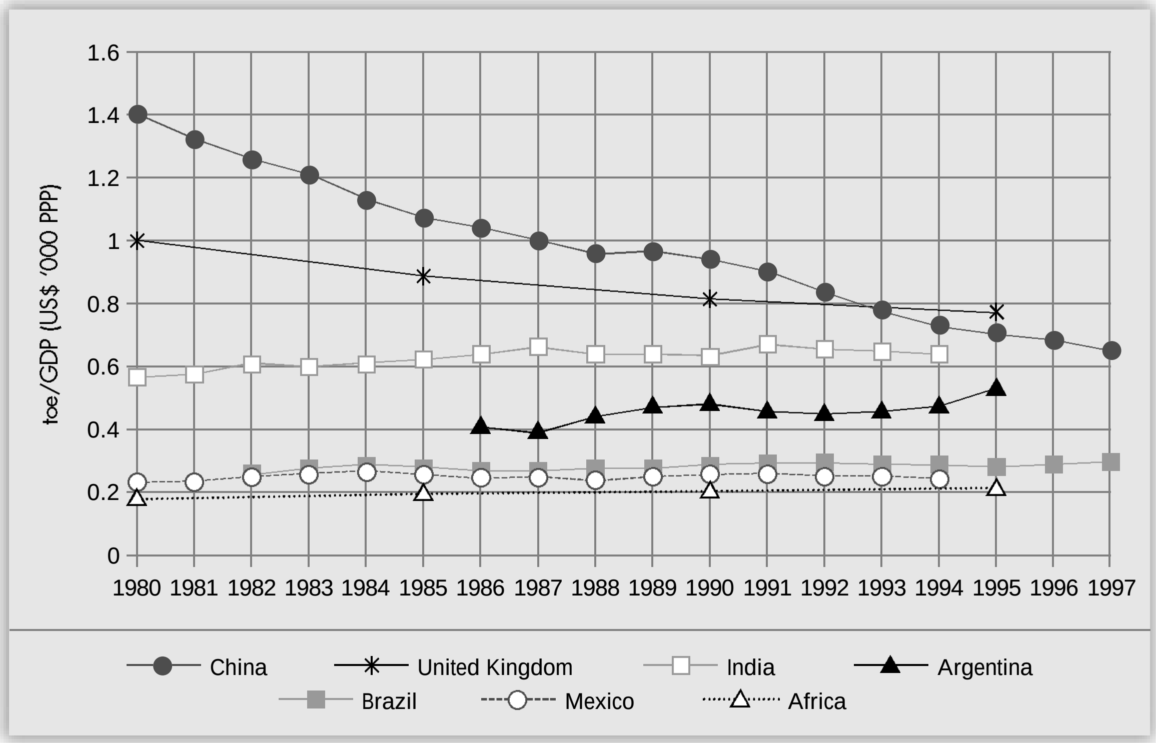
All of the countries included in this report demonstrate a slow decoupling of energy use from economic growth — even countries with relatively low per capita GDP. Each of the case study countries is implementing policies and measures that have reduced the rate of growth of GHGs, although these measures have not been taken primarily for climate protection reasons (see Table 3).

TABLE 3: Policies and Measures Taken by Argentina, Mexico, China, India, African Countries, the UK and Brazil, that Have Resulted in Reduced Rates of Growth in GHG Emissions

Country	Policies	Measures
Argentina	Emphasis on development of hydroelectric and nuclear power sources in 1970s and 1980s	Institution of compressed natural gas programme for transportation in 1984; reduction of natural gas flaring
Mexico	Deregulation and privatisation of energy sector; reduction in energy subsidies	Appliance energy efficiency standards; national reforestation programme; vehicle emission regulations; promotion of mass transportation
China	Reduction in energy subsidies (e.g., coal subsidies reduced from 61% in 1984 to 29% in 1995)	Energy conservation programmes
India	Deregulation of prices for certain grades of coal; reduction of energy subsidies for LPG, petrol, diesel	Renewable energy program (Ministry of Non-conventional Energy Sources; Indian Renewable Energy Development Agency), including subsidies for renewable energy
African countries	Removal of a VAT tax on PV units in most Sahelian countries; reduction in coal subsidies in South Africa.	Emphasis on renewable energy technologies; shift to greater use of natural gas; more efficient power generation
United Kingdom	Privatisation of energy sector; high fuel taxes	Non-Fossil Fuel Obligation (requires certain share of renewable energy); building efficiency standards
Brazil	Reduction in energy subsidies	Ethanol fuel programme; reforestation projects

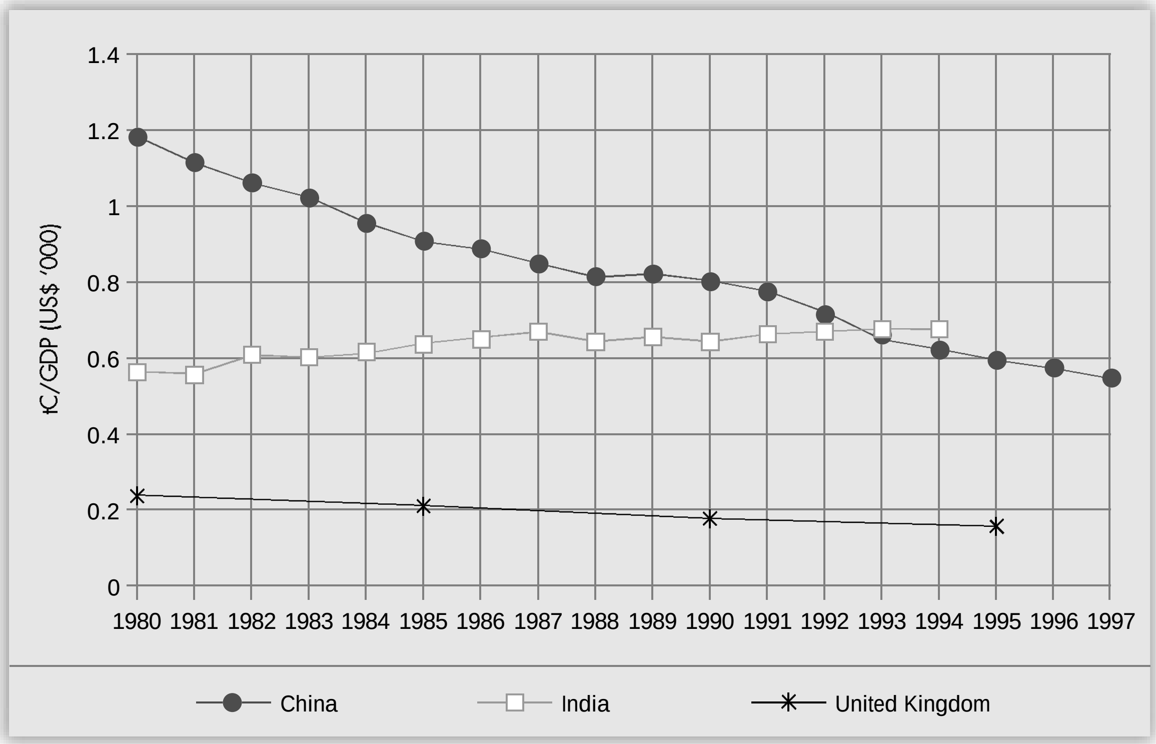
Source: Country case studies, this volume.

FIGURE 3: Energy Intensity for Selected Countries, 1980-1997



Source: Zhang, this volume; Eyre, this volume; Pachauri and Sharma, this volume; Mielnik and Goldemberg, private communication; Davidson, this volume.

FIGURE 4: Carbon Intensity per GDP in China, India, and the UK, 1980-1997



Source: Zhang, this volume; Pachauri and Sharma, this volume; Eyre, this volume.

The impact of the policies and measures of these countries on GHG emissions can be seen in the reduced rates of growth in energy intensity in each country, including declines in energy intensity in recent years in Mexico, China, India, and the UK, and limited increases in Argentina, Brazil, and Africa, as shown in Figure 3.

Trends in carbon intensity of GDP, as shown in Figure 4, are still more informative in examining progress the countries are making to reduce the rate of growth in GHG emissions. In India, carbon intensity reached a plateau in the early 1990s while for both China and the U.K., carbon intensity of GDP has declined significantly.

ADDITIONALITY, BASELINES, AND THE CLEAN DEVELOPMENT MECHANISM

The case studies in this volume shed light on the issue of "additionality", particularly with regard to the design of the CDM. Article 12.5(c) of the Kyoto Protocol requires that emission reductions proposed for certification under the CDM are additional to what would have occurred in the absence of the CDM project. But how can Parties determine "what would have happened" in the absence of the CDM? Because the case studies in this report document the wide range of activities and projects that have taken place in these countries in recent years in the absence of CDM support, they provide a useful point of departure for exploring the issue of additionality and the determination of baselines. By evaluating various proposals for the definition and application of baselines against the experiences of these countries, we can gain insight into the problems that must be overcome in establishing effective baselines and in determining project additionality.

How baselines are defined will have significant impact on the types of projects allowed for crediting and, thus, on both the financial flows and emission reductions created by the CDM. And measuring baselines or assessing additionality is particularly challenging because there is a strong perverse incentive for both the host country and the investing country to inflate baselines and thereby overstate reductions.

A minimum requirement for satisfying the additionality criterion under the CDM is establishing a baseline that embodies the hypothetical idea of "what would have happened" in the absence of the CDM project. Actual project emissions can then be evaluated against the baseline to determine the quantity of certified emission reductions (CERs) that the project generates. A growing literature exists on the merits of various methods for calculating baselines and assessing project additionality (Michaelowa and Dutschke, 1998; Goldemberg, 1998; Chomitz, 1998).

Two general approaches have been suggested for evaluating whether emission reductions are additional to what would have occurred in the absence of a CDM project. First, a proposed CDM project can be compared to other "reference" projects being implemented under similar circumstances without support of the CDM. Second, financial models can be used to determine whether the project would be economically justified without the additional financial resources made available through the CDM.

The case studies in this report point to some of the challenges inherent in the use of financial models to determine "what would have happened without" CDM. Projects that reduce rates of growth in GHG emissions but that are economically justified in their own right are often referred to as "no regrets" projects. In a broad sense, the GHG-limiting actions examined in this report have been "no regrets" actions. These projects or policy changes either provided a good economic return on investment in the case of private sector activities or, in the case of public sector policies or projects, the economic benefits (both private and public) outweighed their economic costs. Since a "no regrets" project would be financially justified even in the absence of the CDM, emissions reductions from such a project would not qualify as "additional." Although we know from the ex-post examination in these case studies that these projects and policies fit a "no regrets" definition, a close look at the types of policies and measures involved shows the significant difficulty inherent in determining "what would have happened without CDM" through a financial assessment.

In several case studies, countries undertook projects that would not show an attractive economic return to a private investor (thus, in a sense, are "regrets" projects) but may well be economically justified if the full economic benefits are calculated.[1] For example, governments undertake fuel-switching projects and promote higher transportation energy efficiency in order to reduce air pollution. Although such projects may not show an economically attractive financial return to a private investor, they may be economically justified if external costs of air pollution are included, such as air pollution impacts on human health or tourism. Economists can attempt to estimate the total costs and benefits in these situations in order to determine whether the project would be "additional"; however, given limited national budgets, not all projects showing net economic benefits would be pursued in any event. Moreover, some types of public benefits may be particularly difficult to factor into financial models. Brazil's ethanol fuel program has long been criticised on economic grounds, but no economic analysis could fully factor in the social and political benefits that the country received related to reduced dependence on imported oil and reduced immigration to urban centres.

On the other hand, while countries sometimes implement projects whose economic benefits are difficult to quantify, in other cases projects that appear to have clear positive economic returns are shelved. Sometimes, institutional obstacles prevent the economic benefits from being captured by the investors or relatively low rates of return mean that limited investment capital is directed elsewhere. The US Environmental Protection Agency-funded Green Lights Program, for example, helped to overcome institutional barriers within firms so that they could take cost-effective steps to instal energy-efficient lighting (DeCunio, 1998). Similarly, the Brazil country study in this volume points to numerous cost-effective opportunities for reforestation in Brazil that are not being pursued, probably because of a lack of capital. Using strict economic criteria, projects such as these could be viewed as "no regrets" activities (for both the private and public sectors), but in fact would not occur without additional investment.

Thus, substantial uncertainty will inevitably surround the determination of whether a project is financially "additional" to what would have otherwise taken place in a country. This uncertainty arises, at least in part, because additionality is policy dependent and not just an economic issue. While empirical information can inform the choice of baselines, the issue is rooted in an irreducible element of policy that cannot be answered technically or "contracted out" to outside organisations or scientists to resolve. Two chapters in this volume, by Michaelowa and Dutschke (Chapter 8) and Baumert (Chapter 9), highlight some of these key policy issues surrounding additionality and baseline issues.

Some experience exists in establishing baselines in the AIJ pilot phase. However, AIJ baselines were agreed to bilaterally and defined according to a variety of criteria and methodologies. Under a crediting system, this will not be possible: although there is no "right" or "wrong" baseline, Parties must use a common framework that is open to third-party scrutiny. In principle, different types of baselines (including national, sector- or project-specific baselines) could be useful in the context of the CDM. Different types of baselines include the following:

National baselines describe the overall "business as usual" (BAU) pattern for carbon emissions for the nation. Annex I governments negotiating the Kyoto Protocol focussed on national baselines, since they indicate how much progress towards GHG reductions to which each country committed relative to BAU. National baselines were also discussed in relation to "voluntary commitments," although a voluntary commitment could, in theory, include commitment to a baseline, target, or programme of activities. National baselines can also be considered as an element in determining project baselines under the CDM, because commitment to a national baseline would help to ensure that the project-by-project emission credits add up to net emission savings across the entire economy. National baselines could be constructed in several ways:

---

[1] To add still more complexity, a number of projects mentioned in the case studies were supported, in part, through development assistance. Without that assistance, governments may not have felt that the benefits justified the costs. The case studies do not attempt to unravel the financial determinants of specific projects. For the purpose of this report, we take those policy changes and projects implemented by countries to be reflective of actions the countries sees to be in its development interests, even though some of those choices are influenced by development assistance.

1. Linear extrapolation of historical levels (static) — this is a poor depiction of reality that tends to overstate future emissions by developed countries and understate future emissions by developing countries.

2. Linear extrapolation of past and recent trends (forward-looking) — also a crude method, but a somewhat more accurate prediction of future trends.

3. Forecast based on economic development, population growth, and possibly exogenous factors (dynamic and forward-looking). This baseline definition offers a better depiction of reality and a more reliable prediction of future emissions (under BAU), provided that the growth assumptions are realistic. However, the costs of drawing up this scenario are high, as it requires careful modelling and accurate data. In addition, since future emissions are policy-dependent, even the most rigorous modelling cannot predict them with precision.

4. Extrapolation of a trend in the carbon intensity of the economy, a relatively straightforward approach but not — due to lack of reliable data — necessarily realistic.

Sector baselines are based on the average carbon intensity for a defined period for a specified set of projects in a particular sector. Like a national baseline, a sector baseline could be defined in static terms based on the average carbon intensity of recent projects (the “observable baseline” of Hamwey, 1998), or could be forward-looking and extrapolated from sectoral development plans or past efficiency gains. Sector baselines suffer from some of the same problems as national baselines — the adequacy of data for certain sectors is limited, and the calculation of dynamic baselines can be costly and time-consuming. In addition, defining the boundaries of the sector can be problematic.

Project baselines are derived from the most likely emissions from the project in the absence of CDM support. A project baseline can, in theory, fully incorporate the technological development and state-of-the-art activities that would take place in the absence of the CDM. Project-specific baseline scenarios, however, do not take indirect effects into account. These can arise when the project uses goods whose production caused GHG emissions, for example. Prices can also influence emissions; they can stimulate greater use of carbon-rich fuels and lead to an increase in GHG emissions, or have the opposite effect. This leads to an additional problem with project-related baselines: if the host country’s production or consumption subsidies distort fuel and electricity markets, a country-related baseline would reflect the distortions. A project-related baseline, however, cannot take this into account. In practice, the distinction between project and sector baselines may be small. The determination of an appropriate baseline “project” to use in estimating emission reductions, for example, is likely to include consideration of trends in that sector.

The country studies examined in this volume illustrate an important conclusion regarding national baselines. A national baseline constructed from net carbon emissions is likely to be relatively variable and highly subject to national policy changes that could influence economic growth. Baselines constructed using net carbon emissions per unit GDP, on the other hand, tend to be less variable and less subject to changes in GDP. In the UK, for example, the economic slow-down in the early 1980s contributed to a noticeable decline in carbon emissions while the trend in carbon intensity during this period remained fairly constant (Figure 4).

For most developing countries, the uncertainty inherent in projections of future economic growth and its effect on carbon emissions would make baselines based on net carbon emissions impractical. Goldstein (1998), for example, has noted that plausible “base case” policy scenarios for China yield a range of carbon emission growth of anywhere from a 30% to a 300% increase by the year 2010. On the other hand, because the trend in carbon intensity is “normalised” for GDP, once countries pass the peak of carbon (or energy) intensity, a gradual decline is fairly predictable under BAU conditions. A country could thus reasonably seek to increase the rate at which the carbon intensity of its economy is declining, without assuming the significant risk of restraining economic growth to achieve its target. On the other hand, a baseline defined in this manner would leave the carbon system open: a country could decrease its carbon intensity with no cap on overall emissions of carbon.

The country case studies presented here indicate that national data are not useful for determining baselines for evaluating specific projects. Changes in carbon emissions, energy intensity, and carbon intensity differ significantly among the various sectors in a country; thus, national averages and trends provide little guidance for evaluating the likely "baseline" scenario for a particular project in a particular sector.

Several of the case studies provide somewhat more support for the utility of a sector baseline. One approach to establishing sector baselines is the "observable baseline." This is based on the presumption that "previous and existing sectoral activities in any national setting, largely implemented in the absence of climate change considerations, provide the best gauge of what future activities would be implemented in near-term national business-as-usual scenarios" (Hamwey, 1998). Thus, for example, an observable baseline for electricity production might be calculated by determining the carbon intensity of the most efficient utilities accounting for some significant fraction (say, greater than 30%) of total power generation in the previous year; otherwise little progress will be achieved. Any plant built with a carbon intensity less than the baseline would be eligible to receive CERs equal to the difference between its intensity and the baseline. After a year, the baseline would be recalculated to include newly constructed plants.

The case studies note the dominance of electricity production, transportation, building efficiency, and, in some cases, industrial activities and land use as major "sectors" contributing to carbon emissions. For the energy and transportation sectors, in particular, the data required for the "observable baseline" approach should be available in most countries. The challenge for sectoral baselines, however, is that in each of the country case studies, significant policy changes dramatically changed the nature of the economically "optimal" project over a relatively limited time. Thus, a sectoral baseline for Argentina before 1970 would have included primarily coal-fired power plants, but the government policy to promote hydropower and nuclear energy meant that the sectoral "average" changed dramatically in the early 1970s. Similarly, restructuring the energy sector in Mexico has meant substantial growth in natural gas power production, something that a sectoral baseline would not have captured. Moreover, with time the baseline would increasingly be weighted by past CDM projects, potentially leading to a too stringent baseline, as the country would not have invested in those projects on its own, as would be desirable.

The use of sectoral baselines is likely to be more relevant to certain sectors, or sub-sectors, than others. For example, Brazil has substantial forest area — amounting to some 60 million hectares — well suited to land use changes such as reforestation and sustainable forest management, which could increase carbon sequestration. Already, for purely domestic economic and environmental reasons, Brazil has undertaken programmes that could increase carbon sequestration, including technical assistance in agroforestry systems to small farmers, restoration of degraded zones through laws requiring that half of all property in the Amazon be maintained in native species, and so forth. Despite these activities and policies, however, the full potential of carbon sequestration in the Amazon is not being realised for a variety of reasons, including the lack of economic incentives. Thus, the opportunity for CDM projects is clear — if the Conference of the Parties allows afforestation as an eligible activity under Article 12 of the Kyoto Protocol.

A sectoral baseline for land use changes can be easily applied only when the alternative land use is known. For example, sustainable forest management (SFM) is currently not economical in the Amazon region, as Salati et al., noted elsewhere in this volume. A baseline for SFM could be established for specific forest types by measuring the most carbon-efficient forest practices accounting for some specified fraction of the harvest in the region. If managers of a timber concession began to implement SFM practices that were more efficient from the viewpoint of carbon sequestration than the baseline, it could be eligible to receive CERs, and the baseline would be ratcheted up the following year. This approach might be considered too narrow given the fact that afforestation should take into account other environmental benefits. In some states in Brazil, almost no degraded land is being reforested. Barring any significant policy changes that make reforestation more economically attractive, this sub-sector trend (no reforestation in the particular state) provides a reasonable BAU sectoral baseline against which the carbon benefits of a reforestation project might be measured.

For other land use activities — for example, establishing plantations in degraded lands in regions where other plantations are already being established, protecting natural forests, or implementing an agroforestry project — it is not clear which ones would be measured for the sectoral baseline. In order to avoid leakage and the problematic baseline determinations that bedevil land use offset projects, it is likely that allocating CERs for such activities will require some combination of project baseline and sector baseline "caps" agreed to by countries wishing to host land use CDM projects.

AIJ experiences have provided considerable information relevant to the design of project baselines, which is reviewed in the chapter by Michaelowa and Dutschke. They conclude that one of the potential concerns about the use of project baselines — the risk of indirect effects and leakage — is probably overstated. (Leakage means that while emission reductions are taking place in one area, increases may be occurring in others.) Although indirect effects through, for example, fuel price changes or shifts among sectors as a result of a particular project no doubt exist, the authors believe these shifts will not necessarily be negative from a standpoint of GHG emission benefits or costs.

In sum, the case studies suggest that confidence in a baseline determined on a project basis (e.g., comparing a proposed project to one or more plausible alternatives in absence of CERs), on a sectoral basis (e.g., comparing a proposed project to the standard project being implemented in that sector), or on some combination of project and sectoral considerations will be greatest if there is a stable policy environment. In many of these case studies, the policy framework affecting baselines has been highly variable, because of fuel price changes, deregulation, privatisation, and other factors. Given this variability, it is important to focus on the "marginal" project when establishing a baseline; that is, to consider the most likely alternative scenario based on the current economic and policy context rather than on historical averages. Finally, there will be higher confidence in establishing baselines for certain sub-sectors where an alternative project scenario is readily apparent — for example, reforesting degraded lands in regions where such lands are not being reforested, switching to SFM in concessions practising traditional forest practises, and building natural gas power plants in the heavily coal-dominated power sector (assuming no recent policy changes).

Given the short time before the CDM becomes operational, it is very likely that, until more experience is gained, baselines on a project-by-project basis will be adopted, as was the case in the AIJ pilot phase. If so, a "dynamic" baseline approach should be used, because any new project that leads to emission reduction lowers the baseline for subsequent projects or subsequent years. Dynamic baselines could, however, lead to uncertainty on the investor's part because the CERs would depend on future adjustments of a project's baseline. Dropping this dependency, and fixing project baselines to a "snapshot" of the host country's dynamic baseline at the time of project certification, could be a more attractive option and provide an incentive for sponsors to participate early in the CDM.

CONCLUSION

Clearly, developing countries are not passive spectators in the arena of climate change. They have already taken significant steps to reduce their emissions of greenhouse gases below the levels that would otherwise occur. Some of these changes are related to modernisation and price reform, and to the "followers' advantage" available to latecomers in the industrialisation process. Since developing countries are taking meaningful measures to comply with the general objectives of the Climate Change Convention, there are no compelling reasons for Annex B countries to postpone ratification of the Kyoto Protocol.

The mechanisms created by the Kyoto Protocol, particularly the CDM, are intended to accelerate the decoupling of economic growth and emission intensity. Their effectiveness requires the reliable establishment of baselines against which certified emission reductions will be measured, as they will become the object of commercial transactions. As stressed above, there are no "right" or "wrong" baselines — what is essential is that countries use a common framework agreed to by all.

REFERENCES

Capoor, K., A.M. Deutz, and K. Ramakrishna, 6-7 June, 1996: Toward Practical Implementation of Article 4.1. of the Climate Treaty. Environmental Defense Fund and Woods Hole Research Center. Paper presented at the U.S. Environmental Protection Agency's Climate Analysis Workshop held in Springfield, Virginia.

Chomitz, K.M., 1998: "Baselines for greenhouse gas reductions: problems, precedents, solutions." Draft manuscript prepared for the Carbon Offsets Unit, World Bank, Washington, D.C.

DeCunio, S.J., 1998: The efficiency paradox: bureaucratic and organizational barriers to profitable energy-saving investments. Energy Policy, **26**(5), 441-454.

Goldemberg, J., T.B. Johansson, A.K.N. Reddy, and R.H. Williams, 1988: Energy for a Sustainable World. Wiley-Eastern Limited, New Delhi.

Goldemberg, J. (ed.), 1998: Issues & Options: The Clean Development Mechanism. UNDP.

Goldstein, D.B., 1998: "Sectoral targets for developing country greenhouse gas emissions efficiency." Manuscript, NRDC, New York.

Hamwey, R.M., 1998: A sustainable framework for Joint Implementation. International Environmental Affairs, **10**(2).

Johansson, T.B., A.K.N. Reddy, and R.H. Williams, 1997: Energy after Rio: Prospects and Challenges. UNDP, New York.

Martin, J.M., 1988: L'intensité énergetique de l'activité économique dans les pays industrialisés: les évolutions de très longues périodes livrent – elles des enseignements utiles? Economies et Sociétés – Cahiers de l'ISMEA, **32**(4), pp. 9-27.

Michaelowa, A., and M. Dutschke, 28-29 May 1998: Creation and sharing of credits through the Clean Development Mechanism under the Kyoto Protocol. Presented at the expert's workshop, "Dealing with Carbon Credits after Kyoto." Callantsoog, Netherlands.

Nielsson, L.J., 1993: Energy intensity trends in 31 industrial and developing countries 1950-1988. Energy, **18**(4), 309-322.

Reid, W.V., and J. Goldemberg, 1997: Developing countries are combating climate change. Energy Policy, **26**(3), 233-237.

WEC/IIASA (World Energy Council/International Institute for Advanced Systems Analysis), 1995: Global Energy Perspectives to 2050 and Beyond. London, UK and Laxenburg, Austria.

World Resources Institute, 1998: World Resources, 1998-1999. Oxford University Press, Oxford, UK.

CHAPTER 1

Argentina's ongoing efforts to lower greenhouse gas emissions

Carlos Enrique Suárez
Chemical Engineer
Fundación Bariloche (FB)
Instituto de Economía
Energética (IDEE)
Río Negro, Argentina

SUMMARY: Although Argentina is not part of Annex I of the United Nations Framework Convention on Climate Change (UNFCCC), it has significantly lowered the intensity of its greenhouse gas (GHG) emissions over a period of 25 years. Efforts that have contributed to this include an emphasis on cleaner fuels (such as nuclear and hydroelectric power and natural gas), a restructuring of the power generation system, promotion of compressed natural gas for vehicle fuel, reduction of natural gas flaring, and reforestation. As a result of these actions, the carbonisation index of the total emissions fell about 25% from 1970 to 1985. Another way of looking at this is that during a period in which energy consumption doubled, absolute CO_2 emissions rose by only 47%. Many of Argentina's efforts have been undertaken at considerable cost to its economy, as reflected in the rise in Argentina's external debt, especially during the 1980s. However, these avoided emissions — past, present, and future — also have an economic value. Based on the direction of climate change negotiations, it appears that Argentina will have no way of being rewarded for its already substantial contributions. It is possible that the country will continue pursuing future efforts in this direction, if socio-economic conditions and international game rules make that possible.

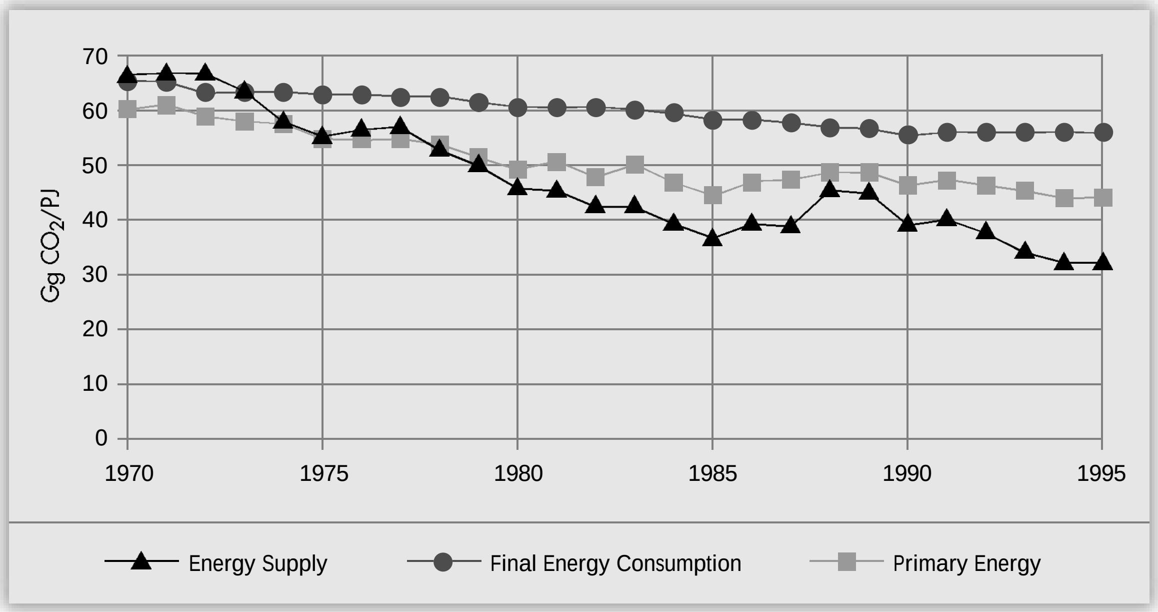
CARBON TRENDS IN ARGENTINA, 1970-1995

Despite considerable economic growth over the past 25 years, Argentina has managed to decrease the carbonisation of its emissions. This chapter discusses the many policies and programmes through which this was achieved.

Carbon dioxide is the most important anthropogenic greenhouse gas (GHG), and its evolution can be used as an indicator for the other five GHGs. Figure 1 shows how the index of carbonisation (expressed in gigagrams of CO_2 per petajoule) has declined in Argentina from 1970 to 1995. As the graph shows, the carbonisation index fell in a systematic and substantial way between 1970 and 1985, resulting in a 25% reduction.

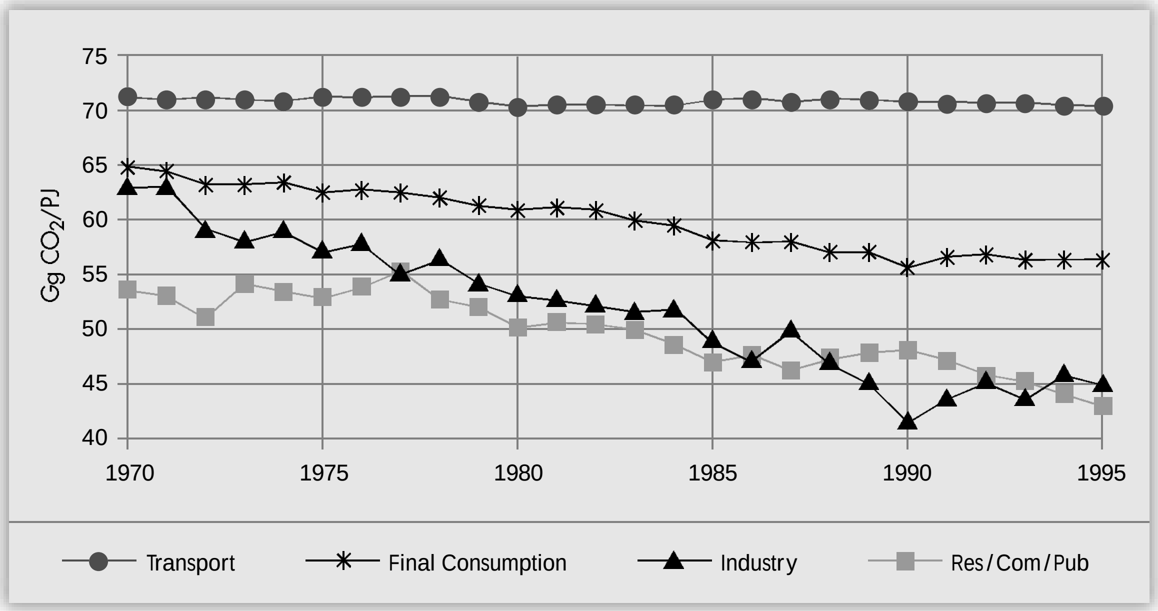
This downward trend is interrupted in the 1985-1989 period, owing mainly to climatic factors (especially the prolonged drought), which required the substitution of thermal power for what was not

FIGURE 1: Index of Carbonisation, 1970-1995



Source: Based on Graph II.11 from the Greenhouse Effect Gas Mitigation Study, UNDP-SECyT, December 1997.

FIGURE 2: Index Disaggregated by Final Energy Uses



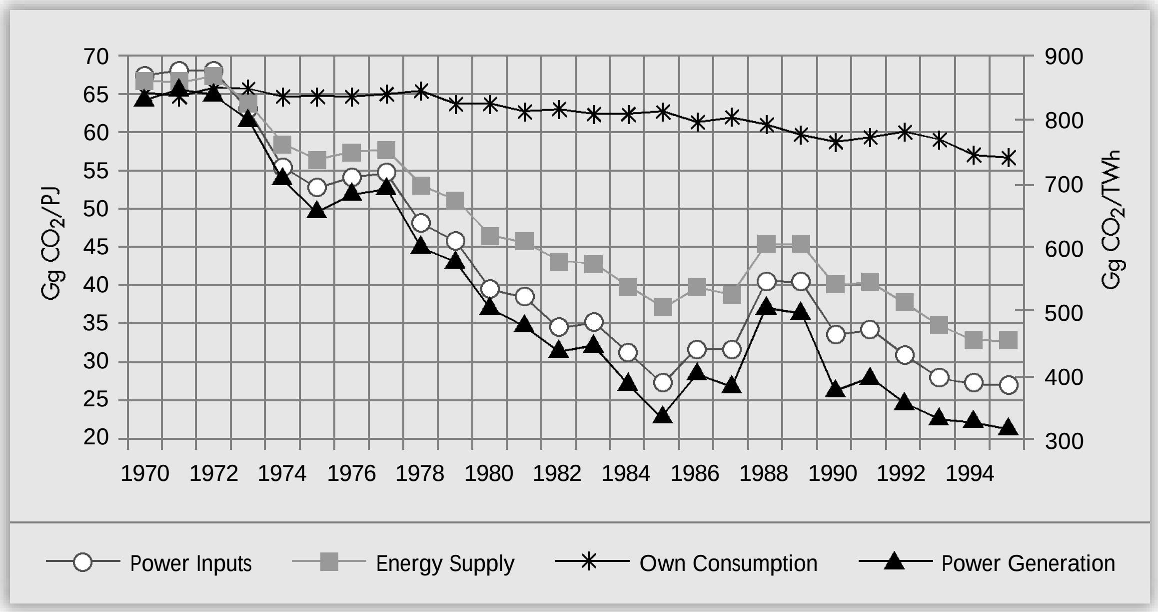
Source: Graph II.13 from the Greenhouse Effect Gas Mitigation Study, UNDP-SECyT, December 1997.

produced by hydroelectricity. The carbonisation index for primary energy continued to fall during the subsequent decade, although at a slower pace than what occurred up to 1985.

Figure 1 also shows decreases occurred both at the consumption level — where the trend continued downward until the year 1990 and then stabilised — as well as at the level of energy supply and conversion, which were significant contributors to the overall decrease in the index of carbonisation.

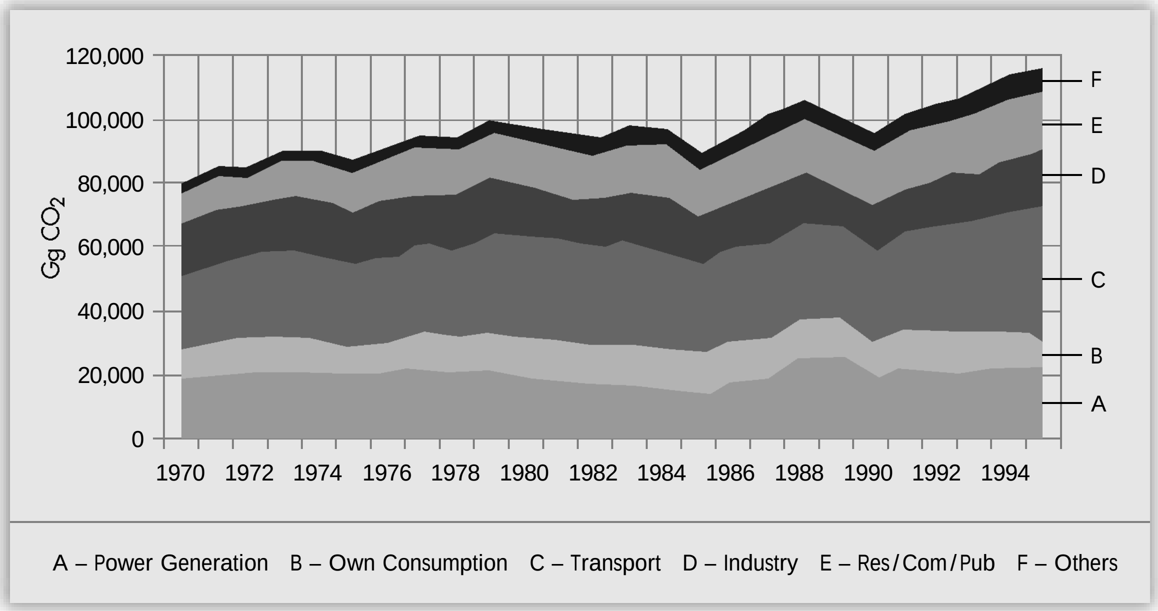
As Figure 2 shows, the most significant reduction in final energy consumption was accomplished by

FIGURE 3: Carbonisation Index for Different Energy Supply Sources



Source: Based on Graph II.12 from the Greenhouse Effect Gas Mitigation Study, UNDP-SECyT, December 1997.

FIGURE 4: Total CO_2 Emission from the Energy System



Source: Based on Graph II.9 from the Greenhouse Effect Gas Mitigation Study, UNDP-SECyT, December 1997.

the industry sector. This reduction — 29% between 1970 and 1985 — was primarily caused by a substitution of natural gas for coal and oil products. The commercial, residential, and public sector shows a somewhat slighter reduction (20% between 1970 and 1995), with most of the reduction occurring between 1977 and 1987. This drop reflects an initial penetration of liquefied petroleum gas replacing oil products, followed by natural gas and electricity. In contrast, the carbonisation index for the transport sector remained nearly stable throughout the period. The index for that sector is currently 55% higher than that of other sectors.

Figure 3 shows that CO_2 emissions by generated terawatt fell 65% — from 65 Gg/PJ to only 23 Gg/PJ — between 1970 and 1985. This resulted from an energy strategy by Argentina to develop its hydroelectric resources and use of nuclear technology to replace thermal power generation based on fossil fuels (coal and/or oil). This strategy was complemented by an emphasis on natural gas, which is the fuel with the lowest emission coefficient.

The reduction in the carbonisation index was interrupted, and temporarily reversed, between 1985 and 1990, partly because of the country's prolonged drought and partly because of institutional factors (namely, the delay in hydroelectric and nuclear facilities). Beginning in 1991, the index of carbonisation again shows a downward trend, although at a lower pace than in the previous period.

Figure 4 shows that, notwithstanding the drop in the index of carbonisation, total emissions tended to rise during economic growth periods (1970-1979, 1985-1988, 1990-1995), while in periods of economic crisis — basically during the 1980s — the downswing in the economy is also reflected in a drop in absolute emissions. A downturn in the economy in the 1980s resulted in emission totals in 1990 comparable to those in 1978.

THE ECONOMIC SIGNIFICANCE OF LIMITING CO_2 EMISSIONS

The socio-economic impact of Argentina's energy policies may be analysed in different ways. On the one hand, they came at significant economic cost to the Argentine people. It is widely known that both hydroelectric and nuclear stations demand a high initial investment, which is paid back gradually over the useful life of the stations. This investment in low-emission energy was part of the reason for Argentina's increase in external debt, especially during the 1980s.

The building of hydroelectric plants and pipelines for the transport of natural gas was accomplished with loans both from international banks like the World Bank and the Inter-American Development Bank, and from other foreign sources (equipment suppliers, export-import banks). This foreign debt attached to major energy projects constitutes a very important proportion of Argentina's debt during that period.

The more recent process of institutional change and use of new high-efficiency technologies makes sense from a microeconomic business viewpoint. However, it comes at considerable costs from a macroeconomic viewpoint, for the following reasons:

- investment in surplus capacity at the power generation level
- the cost of the early retirement of power generation units within their technologically useful life
- the unemployment of a highly trained workforce

It is also possible to calculate the economic value of the savings in CO_2 emission within the historical period compared to the base year. Recent studies analysing mitigation costs in both developed and developing countries clearly show that in most cases these costs reach up to US$100 per ton of saved CO_2. In some cases, the cost may be even higher.

It is estimated that Argentina's emission savings from 1970 to 1995 amounted to some 500 million tons of CO_2, comparing actual emissions with those that would have been registered had there been no changes in the carbonisation index since 1970. This represents a savings of 20% compared to present emissions. If we consider that the capital investments that resulted in this reduction still have an additional useful life of 20 years, on average, we can expect a "savings" of another 800 million tons of CO_2.

If we value such total emissions avoided (1.3 billion tons of CO_2) at a reasonable intermediate economic cost of US$30 per ton, we would have a total value of some US$39.9 billion, which is equivalent to 40% of Argentina's current external debt. Unfortunately, the economic value of CO_2 emission reductions resulting from Argentina's strenuous efforts cannot be recovered. The international climate change negotiations have not considered such contributions made by non–Annex I countries, which are under no obligation to cut down their GHG emissions.

Thus, these "emission credits" from past efforts have no value in the international market, and, in accordance with the game rules currently under discussion, could not be capitalised by Argentina. On the contrary, recent debates have focussed on determining both a mechanism for emission trading and the possibility of “saving” (banking) surplus emissions from a surplus period for a future deficit period.

We deem that it would be fair for the relevant international organisations to analyse how the emission-reducing efforts carried out by non–Annex I countries in the past — with impacts extending into the future — could be valued or rewarded. Certainly some of the Annex I countries could make similar claims, in terms of concrete reductions of CO_2 emissions, but they have formal obligations in this regard. In any case, a comparative analysis of such actions is beyond the scope of this chapter.

OTHER POLICY MEASURES THAT HAVE REDUCED THE CARBONISATION INDEX

In addition to those we have already mentioned, other Argentine policy measures have contributed to Argentina’s significant reduction in the carbonisation index. Among these are a promotion of compressed natural gas for vehicle fuel, a reduction of natural gas flaring in the fields, and natural and commercial reforestation in Argentina. These are discussed below.

TABLE 1: Natural Gas Vehicle Distribution by Country

Country	Vehicle conversions	FIlling stations
Argentina	427,000	580
Italy	290,000	280
Russia	205,000	187
USA	40,000	1,102
New Zealand	25,000	245
Canada	17,200	120
Brazil	14,000	39
Colombia	4,600	22
Indonesia	3,000	12
India	2,500	6
Pakistan	2,500	12
Germany	2,415	55
Chile	2,200	2
China	2,000	10
Venezuela	1,500	20
Australia	1,000	35
Others	4,210	138
Total	**1,044,125**	**2,865**

Source: Twentieth World Gas Conference Proceedings, Copenhagen, 1997, taken from NGV (Lecture given at the Argentine Engineering Association, Buenos Aires, Argentina, 27 pp. and 20 Annexes), Orsi, V., *et al.*, 16 April 1998.

The Natural Gas Vehicle Programme

In 1984, the Government of Argentina initiated a programme to promote the use of compressed natural gas in vehicles, through the elimination of the gasoline tax on natural gas. The programme also supports pilot demonstration projects as well as the building of new filling stations and vehicle conversions in the private sector. As a result, 450,000 vehicles (cabs and private vehicles) use natural gas supplied by some 600 filling stations distributed throughout Argentina. Thus, this fuel can be used not only in the major cities but also for some inter-city travel.

Argentina’s fleet of natural gas vehicles (NGV) is the largest in the world, surpassing that of countries that have used this technology for many years, such as Italy, and of those that are much larger, such as Russia and the United States (see Table 1). Almost 10% of the automobiles in Argentina are NGV — one of the most significant penetrations of this technology at international level.

Promoting NGV has also come at a significant cost to Argentine society. It meant a loss in federal tax revenue of US$3300 billion (over a 14-year period), while private investors contributed some

US$500 million in the construction of specialised filling stations and conversion of automobiles to the new system. Today, this adds up to US$700 million annually in uncollected taxes and US$55 million in private investment.

Regrettably, it has not been possible to convert the urban transport system, which currently operates almost entirely on diesel, to NGV. Such a conversion not only would significantly contribute to GHG reduction, but also would simultaneously reduce urban air pollution, which reaches high risk levels, especially in metropolitan areas. Such a conversion is complicated by the technical complexity of adapting NGV to diesel engines. However, the major stumbling block is economic: since diesel is not taxed, because of its role in agriculture and the urban and inter-city passenger and cargo transport system, conversion would not give users a pricing advantage.

Natural Gas Flaring Reductions

Beginning in 1994, the Government of Argentina adopted specific regulation measures (Resolution 236/93 from the Energy Secretariat) towards reducing emissions related to the flaring of natural gas (such as CO_2 and/or CH_4), which in 1994 amounted to 12.1% of gross production. The strict regulation measures were implemented in a gradual and negotiated way: private producers are allowed a certain amount of flaring, which tapered to the equivalent of 3.0% of gross production by mid-1998. This level is similar to that in most of the industrialised world.

This has caused the volume of flared natural gas to drop — not only in relative but also in absolute terms (from 3363 million m^3 per year in 1994 to just 1957 million m^3 per year in 1997). Thus, even with a significant increase in the production of natural gas — from 23,018 million m^3 per year in 1990 to 37,076 million m^3 per year in 1997 (an increase of 61.0%), there was a reduction in CO_2 and CH_4 emissions. Estimates from the oil industry indicate that this effort to cut down and control the flaring of natural gas, with its savings in GHG emissions, required an investment of about US$350 million.

Afforestation

Argentina was the first country in Latin America and the Caribbean to produce a detailed national inventory of GHG emissions, which was submitted to the Climate Change Commission in 1997. The inventory revealed that the processes of natural forest regeneration, along with commercial reforestation activities, resulted in an estimated CO_2 sequestration level equivalent to 100,191 Gg/year. This CO_2 storage represents about 91.0% of the total CO_2 emissions from the energy sector in 1994.

It also had the effect of decreasing Argentina's net CO_2 emission, which was estimated to be only 33.7% of total gross emission in 1994, when all sources of CO_2 emissions (energy, industrial processes, and land use changes) were considered. About 68% of this storage is attributed to natural recovery of areas that were previously deforested. The remainder (32%) is attributed to afforestation programmes for commercial purposes, which are supported and promoted by the government, and which are expected to be significantly expanded in the near future as a result of new forestry legislation.

It is important to emphasise that actual CO_2 absorption values are probably higher than those estimated, for the studies made could not cover the entire country. However, considerable progress in this respect was achieved with Project ARG/95/G/31, which analysed and quantified GHG emission and absorption. The project was carried out by the Energy, Science, and Technology Secretariat, with Global Environment Facility (GEF) funding channelled through UNDP. With further international support, which is anticipated, Argentina's second national inventory will expand on the initial findings and analyse them further.

FUTURE PROSPECTS

The most recent estimates indicate that the absolute quantities of GHG emissions, in general, and of CO_2 emissions, in particular, will consistently increase in Argentina along with the growth predicted for its economy. Whether the carbonisation index — which represents a good indicator, as we have already pointed out — will continue to decrease depends on a series of policy decisions from public and private investors, and from the game rules set at international levels.

Energy Substitution at the Consumer Level

Considering the high degree of penetration of natural gas and electricity within Argentina's industrial sector, as well as within the household, commercial, and public sectors, we are unlikely to see further reductions in the carbonisation of emissions within these sectors at the level of the final consumer. Hence, future efforts to reduce absolute emissions should focus on energy conservation. In the case of the transport sector, on the other hand, there is the possibility of higher penetration of NGV, especially for urban and cargo transport, if appropriate policy measures are adopted.

There is also a possibility that hydrogen, produced from renewable sources of energy, could penetrate this sector, representing the logical continuation of the process of natural gas penetration already occurring within the energy market. Although a certain rise is expected in electricity's share in the transport system, its absolute value will remain insignificant. In the transport sector, as in the case of the industrial and household sectors, it is also possible to apply energy conservation measures, either by higher use of more efficient transport or through higher technical efficiency in all types of vehicles. In this arena as well, progress will depend on adequate socio-economic policies and promotion methods.

Modification of the Power Generation Structure

Trends in Argentina's energy supply through 2005 will be largely determined by investment decisions already made by public and private generation agents in the installation of thermal, hydroelectric or nuclear stations. Because of rationalisation measures in distribution — which mean significantly lower losses — less generation will be needed to meet demand, with resulting savings on GHG emission.

Under these conditions, it is expected that the carbonisation index emissions will continue falling until the year 2005, basically as a result of the introduction of open and/or combined cycle gas turbines, with high yields and low emissions, which will replace low-yield and low-efficiency thermal stations. After 2005, if current institutional, technological, and economic conditions remain stable, probably only thermal generating stations will be introduced, which will reduce the share of zero-emission sources, leading to a gradual though sustained rise in the share of GHG emissions. Although high-yield, natural gas turbine stations have fewer GHG emissions than thermal stations using coal or oil, they obviously are not as clean as renewable zero-emission sources such as hydro, wind, or solar power.

In order to prevent a rise in the carbonisation index after the year 2005, and thus maintain the downward trend of previous periods, it will be necessary to design and implement institutional and economic measures at the national or international level. These measures should promote investment in the multiple hydroelectric, wind, or solar projects that are possible in Argentina from a technical and natural resources perspective, but that would not be introduced if microeconomic conditions only were taken into account. In that case, obtaining an absolute or relative reduction of GHG emissions will require the Argentine public to face the corresponding incremental cost; otherwise the desired goal will not be met.

Before leaving this point, it is necessary to mention another issue. Argentina is part of a rapid regional integration process at the Mercosur (Argentina, Brazil, Paraguay, and Uruguay) level, with Chile and Bolivia as partner nations. This regional integration will alter investment decisions within both the electric and the natural gas sectors, and offer many opportunities to mitigate GHG emissions. This could occur through the exportation of natural gas from Argentina to replace more polluting fuels in other countries. Or it could come about by importing primary and secondary electricity from countries with hydroelectric stations.

This process will have associated costs and will, moreover, require new accounting rules for GHG emissions from each of the countries involved, since an "exchange" of GHG emissions will take place, either directly or indirectly (for example, when electricity generated with natural gas is exported to a neighbouring nation). The scope of this publication does not allow further analysis of this important issue. However, it is essential to keep in mind, since it will represent another contribution from non–Annex I countries to GHG emission control.

CONCLUSIONS AND RECOMMENDATIONS

A concise analysis of past experience and of future development possibilities at the country and regional levels clearly shows that Argentina was an advocate of “clean” energy well before the issue of climate change was raised at the international level. Years ago, Argentina had begun implementing a series of policies and strategies that limited GHG emissions, through the development of its hydroelectric resources and the intensive use of its natural gas reserves, not only for thermal generation but also as fuel within the transport sector.

These strategies have allowed Argentina to almost constantly reduce the carbonisation index. As a result of these policies, however, Argentina has borne high economic costs, and has been subjected to other types of environmental impacts (for example, nuclear risks and the flooding of fertile land, and impacts on fish and wildlife from hydroelectric stations). The substantial increase in external debt, which Argentines are still paying, has had a serious impact on the country’s economic and social development process.

Beginning in 1990, Argentina has also instituted one of the deepest and most drastic structural changes in the history of its energy system, which was almost entirely privatised and decentralised. It now reflects the market model to a large degree, especially when compared with other systems in Latin America and the Caribbean. This process has brought real economic and environmental benefits, but it has not been without cost either, for it also generated significant macroeconomic problems having to do with unemployment and investment in excess capacity at the power generation stage.

All these changes and adjustment efforts were carried out notwithstanding the fact that Argentina is not a member of Annex I of the UNFCCC and has no legal obligation to cut down its GHG emissions. Unfortunately, international negotiations have not considered ways to recognise or reward such efforts by Argentina and a number of other developing countries, as described in this book.

In the future, Argentina and other countries in the region may be able to make additional contributions to GHG emission control (as part of their essential and ongoing process of economic development), although such contributions will not occur based strictly on market forces. Specific policy measures will be required to optimise socio-economic aspects of GHG emission control consistent with the microeconomic operation of the private sector. In addition to national policy measures, new international procedures are required to transfer economic resources to developing countries as a counterpart to the contributions made by Argentina and others towards a more efficient solution to the global climate change problem.

REFERENCES

Bouille, D., 1996: Desarrollo Sostenible y Cambio Climático: El GEF y el Convenio Marco sobre Cambio Climático (“Sustainable Development and Climate Change: The GEF and the Framework Convention on Climate Change”). Taller Nacional del Fondo para el Medio Ambiente Mundial, PNUD–Ministerio de Relaciones Exteriores, Buenos Aires, Argentina, 9 pp.

Bouille, D. et al., December 1997: *Estudio de Mitigación de Gases de Efecto Invernadero (“Study on Greenhouse Effect Gas Mitigation”).* Proyecto de Estudio sobre el Cambio Climático en la Argentina, ARG/95/G/31–UNDP–SECyT, Buenos Aires, Argentina, 218 pp.

Díaz de Hasson, G. et al., December 1995: La Problemática Ambiental del Sistema Argentino: Su Evolución Histórica (1970-1990) (“The Environmental Aspects of the Argentine System: Their Evolution through History [1970-1990]”). In *Energía, Desarrollo y Medio Ambiente,* No. 2. ALAPE y ENERGE, Centro de Estudios de Energía, COPPE/UFRJ, Rio de Janeiro, Brazil, 60 pp.

Gas y Gas, April 1998: Datos estadísticos para 1997 sobre venteo de gas natural (“1997 statistics on natural gas flaring”). Buenos Aires, Argentina.

Petrotecnia, IAPG, June 1998: Datos estadísticos para 1998 sobre venteo de gas natural ("1998 statistics on natural gas flaring"). Buenos Aires, Argentina.

Prensa Vehicular, Datos sobre el desarrollo de GNC en Argentina ("Data on the development of compressed natural gas in Argentina"), Buenos Aires, Argentina.

Secretaría de Energía de Argentina, 1993: Resolución SE No. 236/93, Normas sobre aventamiento de gas natural ("Regulations on natural gas flaring"), Buenos Aires, Argentina, 1993, 3 pp.

Suárez, C.E., August 1993: Impactos Ambientales del Sistema Energético de América Latina, 1970/1990–1990/2010 ("Environmental Impact of the Latin American Energy System, 1970/1990–1990/2010"), IDEE/FB–OLADE, Bariloche, Argentina, 243 pp.

Suárez, C.E., 10-13 June 1995: Oportunidades Pasadas y Futuras para la Mitigación de GEI en América Latina ("Past and Future Opportunities for GHG Mitigation in Latin America"). Regional Workshop on Greenhouse Gas Mitigation for Latin American Countries, Cancún, Mexico, organised by the Lawrence Berkeley Laboratory, USA, 19 pp.

Suárez, C.E. et al., December 1997: Inventario de Gases de Efecto Invernadero ("Greenhouse Effect Gas Inventory"). Proyecto de Estudio sobre el Cambio Climático en la Argentina, ARG/95/G/31–UNDP–SECyT, Buenos Aires, Argentina, 81 pp.

……

CHAPTER 2

Mexico's policies and programmes that affect climate change

Juan Carlos Belausteguigoitia
Ministry of the Environment
Mexico City, Mexico

Indira López-Bassols
National Commission for the Knowledge and Use of Biodiversity
Mexico City, Mexico

SUMMARY: Energy use has grown rapidly in Mexico, surpassing GDP in real terms because of the country's industrialisation. At the same time, however, a variety of new policies, although undertaken largely for other reasons, have also helped to limit emissions of greenhouse gases (GHGs). New policies have encouraged the substitution of natural gas for fossil fuel and the use of renewable resources. A daylight savings programme helped to curb energy use. Price reform, through a reduction of subsidies, has also become part of the effort to switch to the use of "cleaner" fuels. In addition, more resources are being directed towards storage of carbon through forest conservation, management, and afforestation. These and similar steps are likely to endure and multiply in the future. Mexico will continue to pursue programmes and policies that promote energy efficiency without compromising its development goals.

> *I will consider governments serious when they talk about what actions they will take, rather than what greenhouse gas targets they hope to reach in future years* (Shelling, 1998).

Embroiled in the complexities of negotiating climate change issues, many industrialised countries have not taken specific steps to reduce their greenhouse gas (GHG) emissions. Meanwhile, several developing countries have taken steps in this direction, although not necessarily as a response to the United Nations Framework Convention on Climate Change (UNFCCC). While pursuing national development objectives, these countries have taken significant energy-related actions for environmental, economic, or social reasons; these actions have had the ancillary effect of reducing the rate of growth of their emissions.

Although Mexico has a dual economy (part developed, part poor), deep structural reforms have altered policy and decision-making. These reforms have changed the role of the state from a direct participant in the economy to more of a regulator, a leader of development, and a partner in improving the lot of the country's poorer sectors. Under this new policy orientation, programmes with a health, environment, or poverty alleviation dimension now simultaneously address goals such as energy efficiency, use of renewable energy, and forest conservation and afforestation. Such policies have helped to curb Mexico's CO_2 emissions.

This chapter outlines Mexico's experiences with harnessing carbon emissions. The first part is a brief overview of current trends in carbon intensity of the economy. The second section discusses the broad structural changes that are occurring in the economy and the institutional reforms that are taking place. The third presents a brief analysis of the country's energy use and a range of recent policy changes, including energy sector restructuring, forest protection, urban reorganisation, and price reform.

TRENDS IN CARBON INTENSITY

With total emissions of 327.56 million tons of CO_2 in 1995, Mexico ranks high in terms of carbon intensity. However, it contributes just 1.48% of the global total. On a per capita basis, Mexico ranks 72nd, emitting 3.46 tons of CO_2 per person in 1995 (Government of Mexico, 1997, p. 7).

Mexico's high carbon intensity, shown in Figure 1.1, can be partly accounted for by the fact that GDP is calculated on the basis of US dollars. However, if we look instead at the comparative intensities using the purchasing power parity (PPP) measure developed by the International Energy Agency (IEA), the results appear much different. When we use this alternative calculation, Mexico's carbon intensity is reduced, as shown in Figure 1.2, by more than half (from 1.18 to 0.51) This result is lower than that in other countries such as the United States (0.84 kg CO_2/90 US\$ PPP), Canada (0.83), Germany (0.64) and the United Kingdom (0.57).

Figure 1.3 shows trends in energy intensity among several countries (figures not adjusted for PPP) and Mexico ranks quite high. However, when one considers energy intensity per capita, Mexico is lower than most OECD countries.

In response to its UNFCCC commitments, Mexico developed the Climate Change Country Study in 1990, and, in 1996, updated the 1990 inventory of anthropogenic GHG emissions by sources and sinks, future emissions scenarios, climate change scenarios, and vulnerability and mitigation studies (see Table 1). This inventory is providing useful, comparable data. As Table 1 demonstrates, CO_2 is the country's largest anthropogenic GHG (444,489 Gg), and the energy sector scores the highest in total CO_2 emissions. Emissions come mainly from the use of fuels for energy generation, changes in land use, agriculture, and emissions due to fuel and gas leaks (Government of Mexico, 1997, p. 28).

FIGURE 1.1: Comparative Carbon Intensities

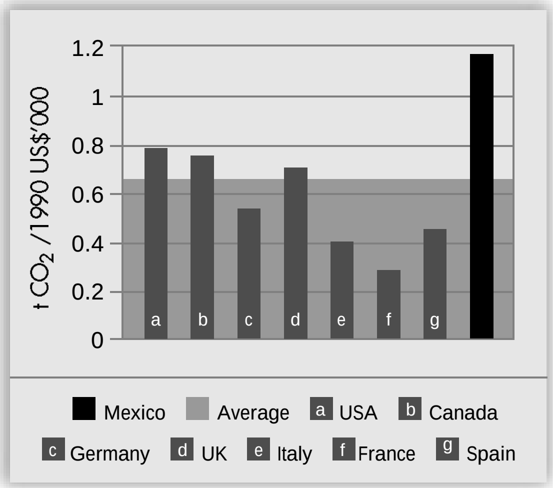


FIGURE 1.2: Comparative Carbon Intensities (1990 US\$ PPP)

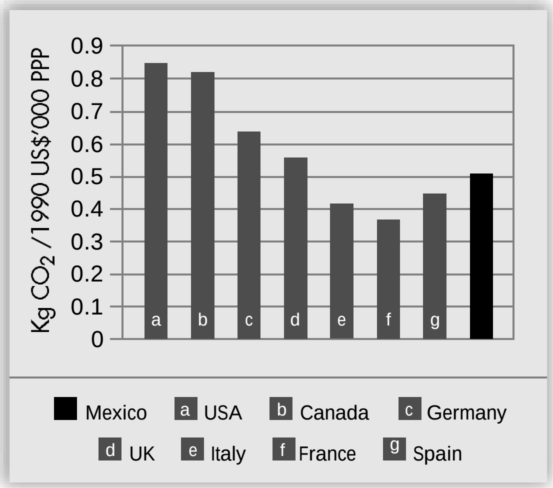
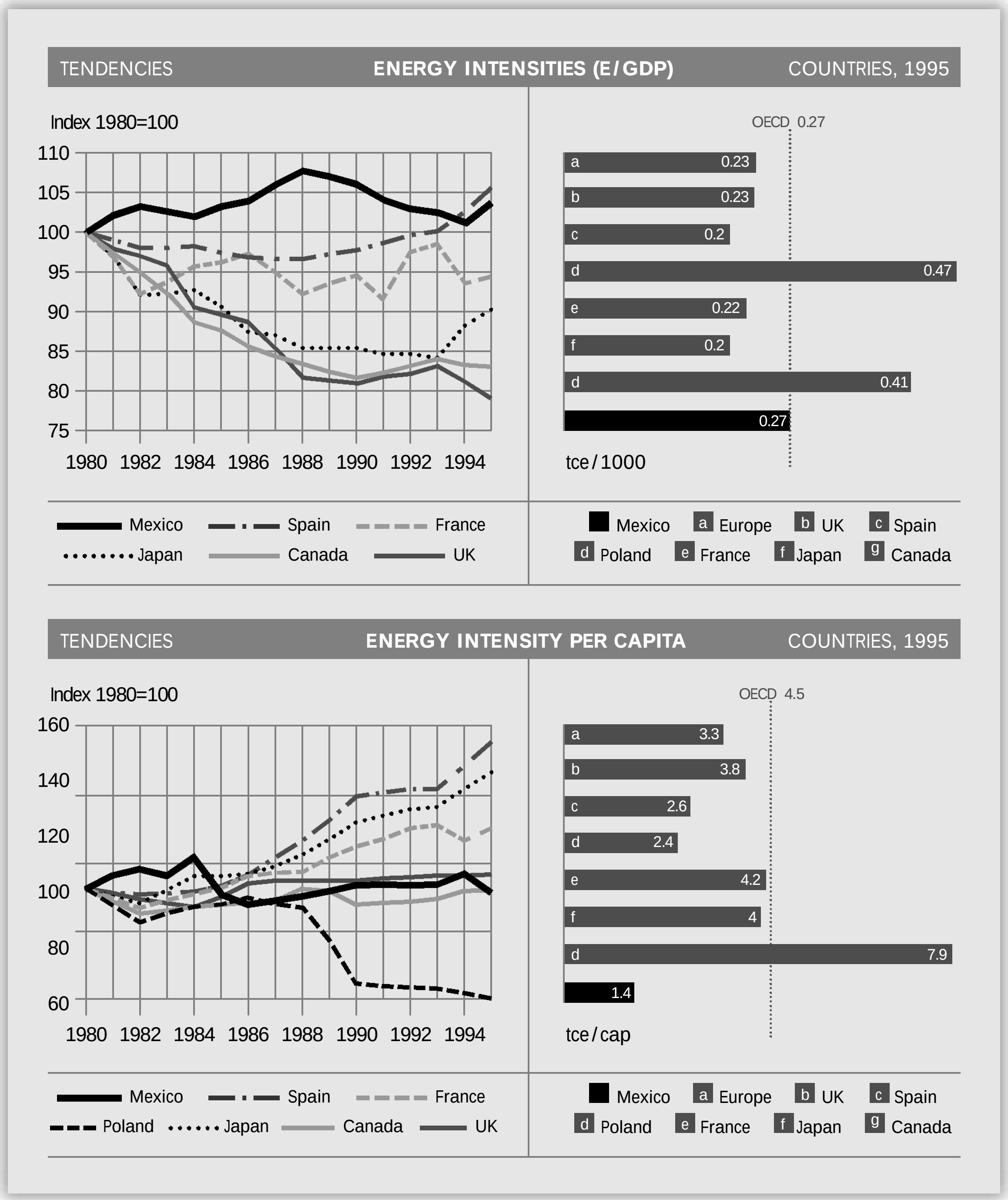


FIGURE 1.3: Energy Trends since 1980



Source: IEA-OECD, 1998a.

As Table 1 demonstrates, 99.2% of direct GHG emissions are CO_2. The results shown in Figure 2 indicate that changes in land use are responsible for 30.56% of CO_2 emissions. Other significant contributors include the transformation and energy production industry (24.40%), the transport sector (21.31%), industry (14.62%), industrial processes, and residential and commercial activities (8%) (Government of Mexico, 1997, p. 30).

TABLE 1: Summary of GHG Emissions by Sources and Sinks for Mexico in 1990[a] (Gigagrams)

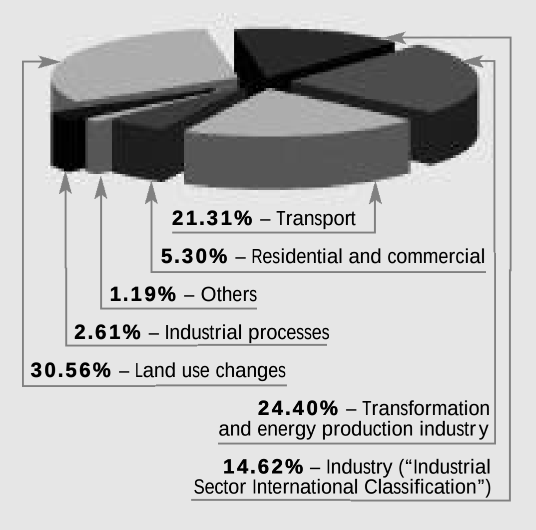
Types of greenhouse gas by sink and source	CO_2 Top-down[b]	CO_2 Bottom-up[c]	CH_4	N_2O	NO_X	CO	NMVOC[d]
Total national emissions and removals	459,278.333	444,488.970	3641.655	11.779	1012.879	11032.531	800.770
1 Energy (fuels + leaks)	311,800.000	297,010.637	1081.358	3.962	962.792	8725.420	800.770
2 Industrial processes	11,621.000	11,621.000					
3 Agriculture			1793.297	5.817	11.082	195.111	
4 Land use change and forestry	135,857.333	135,857.333	241.000	2.000	39.000	2112.000	
5 Waste			526.000				

[a] This table follows an established format. Therefore, starting with N_2O, the types of gases are all indirect GHGs.
[b] Estimated from national statistics for fuel supply and emission factors for each fuel.
[c] Estimates based on demands by sector, which are then aggregated.
[d] Non-methane volatile organic compounds.

Source: México, Primera Comunicación ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático. Government of Mexico, 1997, p. 29.

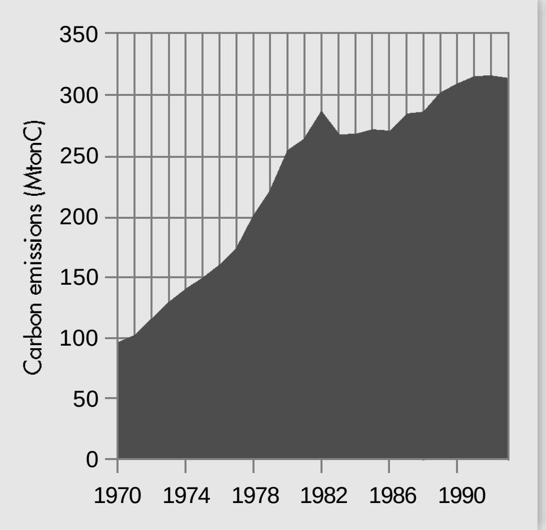
Figure 3 presents carbon emissions over time. From 1970 until 1982, there was a continous rise, from 98.22 MtonC to 285.35 MtonC. From 1982 until the following year, carbon emissions decreased, and then they stabilised for a few years. From 1988 on, emissions increased again, but at a lower rate, from 284.16 MtonC to 314.11 MtonC.

FIGURE 2:
CO_2 Emissions in Mexico



Source: México, Primera Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático, Government of Mexico, 1997, p.30.

FIGURE 3:
Mexico's Carbon Emissions, 1970-1993*



Source: Data from Dirección de Cambio Climático, Unidad de Cooperación y Convenios Internacionales, INE, 1998.

* Does not include emissions from land use changes.

STRUCTURAL AND INSTITUTIONAL REFORMS

At the end of the 1980s, environmental concerns were given priority. The subsequent creation of a number of new ministries, commissions, and legal instruments underscores their political importance. During 1997, the federal government established an Inter-ministerial Committee in charge of co-ordinating issues that affect climate change among several agencies. The creation of this Committee is important because it reflects the first governmental attempt to coordinate climate change issues in a cross-sectoral way. It meant involving not only the Ministry of the Environment, Natural Resources, and Fisheries (SEMARNAP), and the Ministry of Energy, but also the ministries of Foreign Affairs, Commerce and Industrial Development, Agriculture, and Social Development, among others, in decision-making.

The economic policies that Mexico has followed since 1983 — including fiscal and budgetary reforms, privatisation of public enterprises, trade liberalisation, and deregulation — have had a significant impact on several areas relevant to this study. They were implemented after the 1982 economic crisis, which made evident the limits of the previous development model that sought economic growth through an expansion of government expenditures. The administration that started in 1983 pursued a set of macroeconomic adjustment and stabilisation policies between 1983 and 1987, followed by structural reforms that modified key microeconomic elements of the economy between 1988 and 1993. The broad strokes of these reforms are still being followed, despite the crisis triggered by the 1994 peso devaluation.

The combination of such policies has generated a more competitive environment, hostile to inefficiencies and waste, in both the public and private sectors, as well as a restructuring of the public sector and increased participation of private activity in the economy. This privatisation has had many effects, including the increased distribution of natural gas, in which the private sector has been playing an important role. In May 1995, Article 27 of the Mexican Constitution was modified to allow private companies to engage in natural gas transport, storage, and distribution. This change is stimulating the use of natural gas in the business and residential sectors (Government of Mexico, 1997, p. 55). Natural gas is now available to about 70% of the power plants located in environmentally critical areas (INE, 1998, p. 4). In the electric sector, co-generation is now allowed. Private investors can produce electricity for their own use, and sell the surpluses to the Federal Electricity Commission (CFE). Private enterprises with the sole purpose of generating electricity can also sell it to the CFE, which will, in turn, distribute it to end-users.

During the 1990s, Mexico witnessed the strengthening of its institutional and juridical environmental platform, supported by a growing partnership between the government and civil society. In 1994, SEMARNAP was created with a mission to counteract environmental degradation, while establishing the foundations for a transition towards sustainable development. It also coordinates the work of several other agencies.

THE ENERGY SECTOR

Mexico's economy grew more than 5% in 1998, and its demographic growth is around 1.7% annually. Its number one priority is more equitable, sustainable economic development. Thus, the role of the energy sector, which literally fuels economic growth, becomes crucial. Since energy consumption also generates additional costs to society, however, a balance must be attained. Ideally this balance should include sufficient energy production to cover the country's needs while it switches to cleaner fuels. In other words, Mexico needs to increase energy efficiency and promote gradual structural changes in its consumption patterns.

Since 1950, because of Mexico's population growth and industrial boom, CO_2 emissions have also grown. The following analysis looks at fuel consumption by sector for the years 1990-1996. As shown, there is a clear increase in the use of cleaner fuels, such as natural gas, with a switch away from using fuel oil.

TABLE 2.1: Energy Sector CO_2 Emissions, 1990-1996 (millions of tons of CO_2)

	1990		1996		Average annual growth 1990/1996
		%		%	%
Carbon	8.017	6.5	19.165	13.5	15.6
Coke	0.179	0.1	0.117	0.1	(6.8)
Liquefied gas	1.714	1.4	1.806	1.3	0.9
Gasoline	5.166	4.2	1.746	1.2	(16.5)
Kerosene	1.277	1.0	1.356	1.0	1.0
Diesel	4.471	3.6	3.788	2.7	(2.7)
Fuel oil	71.897	58.4	70.881	50.0	(0.2)
Natural gas	30.459	24.7	42.797	30.2	5.8
Total	**123.180**	**100.0**	**141.656**	**100.0**	**2.4**

Source: Secretaría de Energía, Subsecretaría de Políticas y Desarrollo de Energéticos, Dirección General de Política y Desarrollo Energético Climate Change, and the Energy Sector. Internal document, 1998a, p. 11.

TABLE 2.2: Energy Sector Consumption, 1990-1996 (Mtoe)

	1990		1996		Average annual growth 1990/1996
		%		%	%
Carbon	79.283	4.9	189.519	10.1	15.6
Coke	1.575	0.1	1.029	0.1	(6.8)
Liquefied gas	25.822	1.6	27.211	1.5	0.9
Gasoline	70.819	4.3	23.933	1.3	(16.5)
Kerosene	16.880	1.0	17.926	1.0	1.0
Diesel	57.347	3.5	48.584	2.6	(2.7)
Fuel oil	887.822	54.5	873.346	46.7	(0.3)
Natural gas	488.648	30.0	686.590	36.8	5.8
Total	**1628.196**	**100.0**	**1868.138**	**100.0**	**2.3**

Source: Secretaría de Energía, Subsecretaría de Políticas y Desarrollo de Energéticos, Dirección General de Política y Desarrollo Energético Climate Change, and the Energy Sector. Internal document, 1998a, p. 11.

From 1990 to 1996, the national demand for fuel oil was reduced by 1.2% annually. While annual energy consumption has increased at 2.6%, total CO_2 emissions derived from burning fossil fuel have shown a slightly lower average annual increase (2.5%).

Thus, one can conclude that in recent years Mexico has been using cleaner fuels to fulfil its needs. In addition, the Ministry of Energy has outlined a few alternatives to diminish GHG emissions without compromising Mexico's economic growth rate: using market mechanisms such as prices and fiscal incentives to adjust the demand for fuels, widening the supply of energy to include more renewable sources and cleaner fuels, using end of pipe treatments, and sequestering additional carbon in forests.

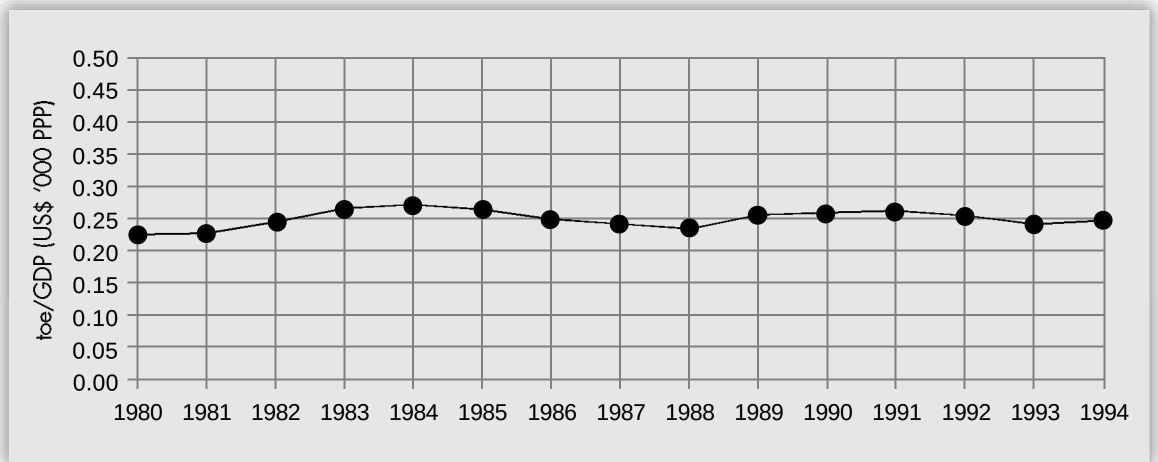
Although these alternatives and projects vary in terms of financial, economic and social costs/ benefits, the energy sector's challenge will be to combine these alternatives in such a way that both economic growth and social well-being are protected. At the same time, the supply of cleaner fuels (unleaded gasoline, for example) should be maintained, regardless of cost, in order to minimize

GHG emissions. The participation of key programmes in this effort is described below.

Figure 4 shows the historical trends of the energy intensity of Mexico's economy as a whole. The long-term trend has been a fairly stable energy/ GDP ratio.

For a quarter century, energy self-sufficiency was Mexico's number one priority. The domestic energy production increased throughout the period 1970-95, although less rapidly after 1989. Today, government attention has focussed on other goals, such as energy conservation and economic and technical efficiency in the use and supply of energy (Government of Mexico, 1997, p. 53). In particular, environmental concerns about the excessive and inefficient use of energy have started to permeate policy. Thus, new programmes promote energy efficiency, the use of improved vehicle fuels, the substitution of natural gas for fossil in environmentally critical zones and in the industry sector, and the use of alternative and profitable sources of energy.

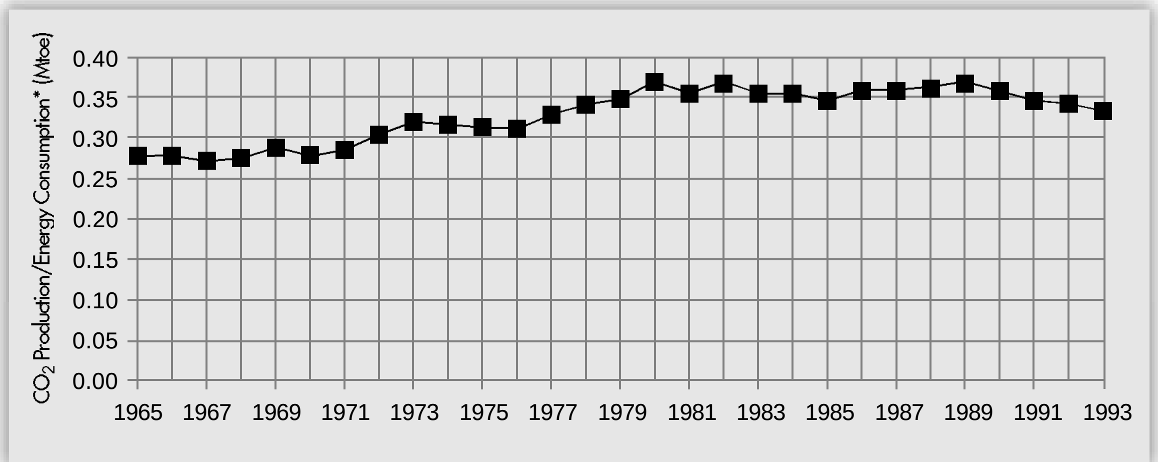
FIGURE 4: Energy Intensity* for Mexico, 1980-1994



*GDP in US$ 1987.

Source: J. Goldemberg and O. Mielnik, 1999 (private communication)

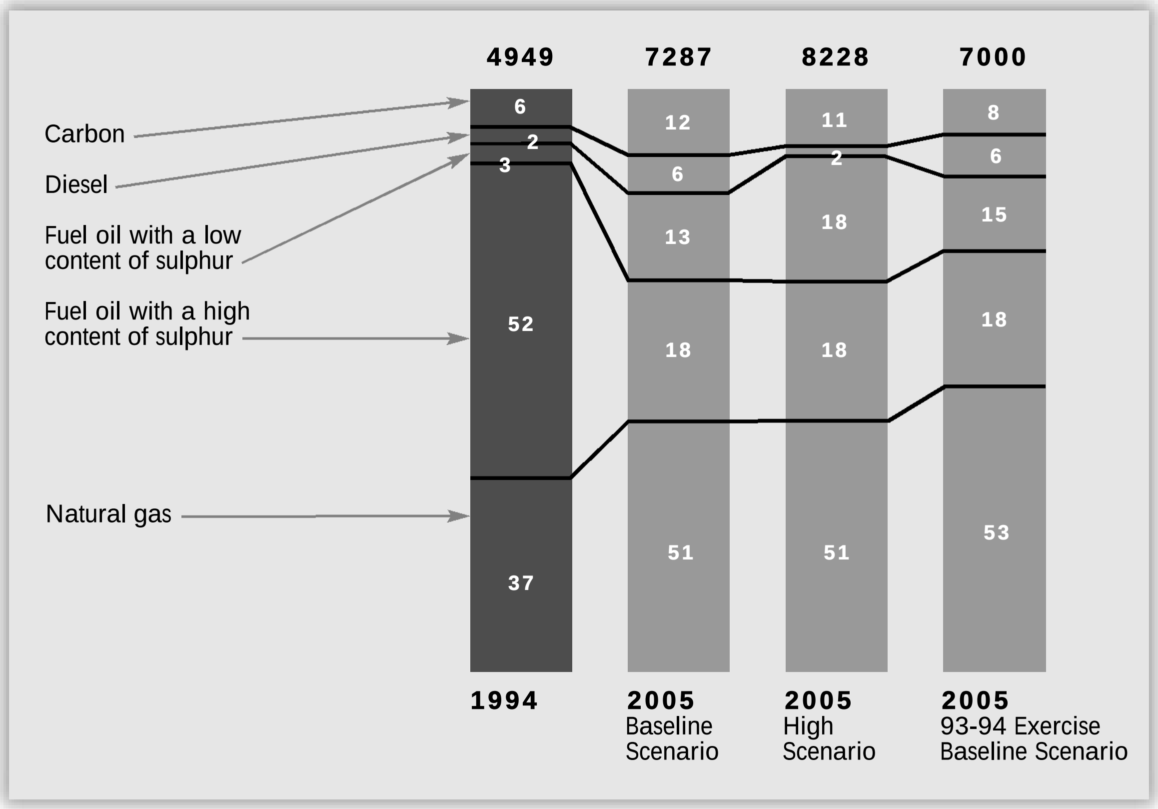
FIGURE 5: The Carbon Content of Mexico's Energy Supply, 1965-1993



* Final energy consumption by sectors includes total solid fuels, firewood, sugarcane residuals, coke, total petroleum, liquefied gas, gasoline, kerosene, diesel, fuels, total natural gas, non-associated dry gas, natural gas, and electricity.

Source: Data from Balance Nacional de Energía 1996, Secretaría de Energía, 1996, and INE, Unidad de Cooperación y Convenios Internacionales.

FIGURE 6: Evolution of the Optimal Profile for Fuels in Fixed Sources for Mexico*



*In millions of cubic feet equivalent (percentage).

Source: Resultado de los Temas Abordados por el GPC en el Periodo Marzo-Agosto de 1995, Grupo de Combustiles, 14 de Sept. 1995.

Figure 5 shows the carbonisation of the energy supply, in other words the ratio of CO_2 emissions (in millions of tons) to energy consumption between 1965 and 1993. Three general trends can be seen in this figure: a general increase from 1965 until 1980, a flattening from 1980 until 1989, and a decrease after that.

In the residential, business, and public sectors, the consumption of natural gas reached its peak of 53.9% during 1996, compared to fuel oil consumption of 46.1%.[2] In the national electric system, the use of natural gas increased by 7.8% annually, on average, between 1984 and 1996, while the use of fuel oil increased more slowly — an average of 3.1% annually. In the industry sector, between 1989 and 1996 the use of natural gas increased 5.4% annually on average; meanwhile, fuel oil use declined by an average of 2.5% annually (SE, 1998b, p. 2).

The Fuel Policy Group (GPC) was formed in 1993 with the participation of several government ministries, a regional power company, and the Federal Electricity Commission. GPC's long-term (1994-2005) proposal for Mexico, the Integrated Fuel Policy, is intended to reduce the use of fuel oil (high in sulphur) and increase the use of natural gas. The proposal also suggests activities to reduce the emission of pollutants, such as lead and sulphur oxides, as well as GHG emissions.

By the year 2005, the share of natural gas in the optimal profile for fuels in fixed sources[3] for Mexico is expected to increase from 37% (1994 levels) to 53%, almost doubling the present demand (see Figure 6). This shift will occur for three reasons:

---

[2] *This refers to the total 100% participation, which includes natural gas and fuel oil.*

[3] *Fixed sources do not include the transport sector.*

- Current electrical generation plants will convert to natural gas for economic and ecological reasons.
- The combined cycle of this new electrical generation capacity will gain importance, partly because of its high technological efficiency.
- The construction of new natural gas industries in environmentally critical zones will be given priority (GPC, 1995, pp. 1-17).

The economic forces at work include electrical energy supply versus demand, relative pricing among fuels, and restrictions imposed by environmental regulations. In addition, the use of natural gas by Pemex will allow that company to fulfil environmental regulations in the refineries that are located in critical zones, such as Cadereyta, Madero, and Minatitlán. These refineries have no way of obtaining fuel oil with a low sulphur content.

TABLE 3.1: Fuel Structure of Industrial Fuel Consumption/Energy Type

Type of fuel	Scenario 1	Scenario 2
Coal	5%	8%
Petroleum products	63%	39%
Gas	32%	53%

Source: INE, Estudio de Costo-Beneficio,
Norma Oficial Mexicana 085, Mexico City, 1994.

As mentioned previously, in order to increase the consumption of natural gas and reduce that of fuel oil, significant investments are needed. A total of US$7.6 billion would be the minimum required; US$6.5 billion would be necessary to increase the crude oil refining capacity and infrastructure construction, and US$1.9 billion to increase the supply of natural gas (INE's Estudio de Costo-Beneficio, 1994). Table 3.1 shows two possible scenarios: first, fuel consumption under the present policy (scenario 1) and second (scenario 2), the consumption structure as it is projected to be under the Integrated Fuel Policy (INE's Estudio de Costo-Beneficio, 1994).

Under current policy, economic growth would stimulate the consumption of industrial fuels and carbon emissions would, in turn, increase. Emissions are expected to increase by 50.1% unless fuel consumption changes, or by 45.5% with a natural gas substitution, as shown in Table 3.2. Under the Integrated Fuel Policy initiative, carbon emissions would be reduced by 3% by 2005 with constant usage patterns and continuing trends in economic growth. When the consumption of high-carbon fuels is reduced through the substitution of cleaner fuels, a decrease in the emissions of GHG follows. This reduction of carbon emissions is a by-product of reducing costs and also satisfies energy demand (scenario 2). This scenario amplifies the energy supply without adding costs and while integrating environmental values (Belausteguigoitia and Ibarrarán, 1995, p. 366).

TABLE 3.2: Estimated Emissions under Alternative Scenarios

	Present policy	Present policy	% Increase	New policy	% Increase
	1993	2005	1993-2005	2005	1993-2005
Carbon (in millions of tons)	3856	5786	50.1%	5611	45.5%

Source: Estimates by Unidad de Análisis Económico y Social, SEMARNAP, 1995.

ENERGY CONSERVATION AND EFFICIENCY

Energy conservation and efficiency efforts have been promoted mainly through two institutions: the National Energy Savings Commission (CONAE), created in 1989, and the Electrical Energy Savings Trust (FIDE), established in 1990.

CONAE has initiated energy-saving programmes nationwide, promotes co-generation in the industry sector, and administers the Mexican Official Standards (NOM), which regulate energy consumption of equipment and electric appliances. From

TABLE 4: Energy Saved and Emissions Avoided through Hydroelectric Plants

Project: Hydroelectric plants	**1993**	**1994**	**1995**	**1996**	**1997**
Energy savings (GWh)	180	492	2513	3658	3925
Fuel oil savings (Mtoe)	0.045	0.122	0.619	0.896	0.958
Carbon avoided (tons)	39,910	107,969	547,172	791,895	846,753
CO_2 emissions avoided (tons)	146,337	395,886	2,006,297	2,903,615	3,104,761

Source: Secretaría de Energía, Subsecretaría de Políticas y Desarrollo de Energéticos, Dirección General de Políticas y Desarrollo Energético. *Principales Políticas Energéticas Enfocadas a la Disminución de las Emisiones de Gas Efecto Invernadero* (1993-1998). Internal document, 1998c.

January 1996 until December 1997, CONAE published 7 NOMs,[4] established 13 labs, and created 378 verification units (CONAE, 1998, p. 7). By 1998, 4 million products sold in Mexico had to comply with these energy-efficiency NOMs; this generated annual energy savings in excess of 2 million MWh (CONAE, 1998, p. 7).

Although co-generation was seriously affected by the 1994 economic crisis, new projects are starting to flourish. CONAE has been encouraging enterprises to consider their co-generation potential, and has created a Co-generation Projects Promoting Commission with representatives from the public and private sectors. In addition, the Energy Regulatory Commission (CRE) has granted 25 co-generation permits, with a capacity close to 1130 MW. At the moment, only 13 projects are operating, with an installed capacity of 231 MW and an annual generation of 1575 GWh. For the year 2007, an installed capacity of 3800 MW is expected to be in operation (SE, 1996).

CONAE, in collaboration with the Ministry of Energy, has also promoted renewable energy through wind and hydroelectric plants. The 1994 Energy Balance Report stated that 0.01 petacalorie of wind energy was generated. In 1995, it had increased to 0.015 petacalorie.

The total nationwide hydroelectric potential is estimated at 3000 MW. Hydroelectric plants saved up to 3924.84 GWh of energy and 0.958 (Mtoe) of fuel oil in 1997, as shown in Table 4. This translates into 3.1 million tons of CO_2 that were not emitted during 1997.

FIDE has also implemented several energy-saving activities, including demonstration projects and activities across the main consuming sectors all around the country. It has instituted a successful incentive program in two sectors: households and the commercial sector lighting system, which includes projects in industry and business. The fundamental objective of the household project was to increase energy efficiency by replacing incandescent bulbs with compact fluorescent lamps (CFLs). In 1995, CFE initiated the ILLUMEX project in Monterrey and Guadalajara

TABLE 5: Energy Saved and Emissions Avoided through Daylight Savings

Project: Daylight Savings	**1996**	**1997**
Energy savings (GWh)	943	1100
Fuel oil savings (in Mtoe)	0.231	0.268
Carbon avoided (tons)	204,133	237,316
CO_2 emissions avoided (tons)	748,488	870,159

Source: Secretaría de Energía, Subsecretaría de Políticas y Desarrollo de Energéticos, Dirección General de Políticas y Desarrollo Energético. *Principales Políticas Energéticas Enfocadas a la Disminución de las Emisiones de Gas Efecto Invernadero* (1993-1998). Internal document, 1998c.

---

[4] *These are the seven NOMs published by CONAE: 1) NOM-010-ENERGY-1996: Submergible water pumps; 2) NOM-011-ENERGY-1996: Central air conditioning units; 3) NOM-012-ENERGY-1996: Low-capacity boiler; 4) NOM-014-SCFI-1997: One-phase electric motors; 5) NOM-015-ENERGY-1997: Domestic refrigerators and freezers; 6) NOM-017-ENERGY-1997: Compact fluorescent lamps; 7) NOM-018-ENERGY-1997: Thermal insulation buildings (CONAE, 1998, p. 10).*

by selling CFLs, and 1.8 million of these lamps have already been installed. Highly competitive prices, plus the option of paying in several instalments through electric bills or in cash, have created a market for this new lighting system.

By the year 2000, 6.1 million of these lighting units will have been sold. Savings are expected to reach 2722 GWh in consumption and 300 MW in demand. As a side effect, the use of CFLs will lead to cleaner air, based on annual fuel savings of 265,000 barrels of oil per year, which would in turn reduce CO_2 emissions by 27,500 tons C per year (UNDP, 1997, p. 152).

Finally, the introduction of daylight savings two years ago has proven to be successful. Table 5 shows that the CO_2 emissions avoided added up to 748,488 tons for 1996 and 870,159 tons for 1997. Total energy savings due to this programme are equivalent to 0.83% of the annual consumption of electricity in the entire country. Savings obtained in 1997 alone are equivalent to a reduction of 1.76 million tons of fuel oil, or 0.189% of the total CO_2 emissions in Mexico in 1990.

Additionally, the Inter-American Development Bank (IDB) has granted a US$23.4 million loan to CFE for a project dealing with energy efficiency, the highest grant ever authorised by the IDB for an energy-saving programme. The growing number of participants in the domestic sector, as well as in the industry and business sectors, is indicative of the growing public awareness of and interest in energy conservation. Furthermore, it confirms the pioneering role of FIDE, which provides technical assistance to other Latin American institutions. Although many challenges lie ahead, including the consolidation of a real "energy-saving culture," FIDE projects have already yielded a total economic benefit of aproximately US$61.7 million (1556 GWh in energy and 395 MW in power).

In the next decade, Mexico will have to confront serious challenges regarding its national fuel strategy. The growing demand for electricity and fuels by the industry sector and households will need to be satisfied. Similarly, environmental regulations will be more stringent. Thus, it is likely that consumption of natural gas will play an even greater role in the future. However, this implies making the necessary investments to modify the fuel demand structure.

PRICE REFORM

A reduction of subsidies leading to higher fuel prices is essential to lowering the rates of growth in consumption and carbon emissions. For the purpose of this analysis and as a starting point to assess the reach of price reform in Mexico, real prices of heavy fuel oil, diesel, gasoline, and natural gas in Mexico and the United States have been compared (Figures 7.1 to 7.4). In general terms, the Mexican trend in real prices for all of these fuels has been increasing — except for the real price of natural gas, which is decreasing. And Mexico's prices tend to be higher than those in the US. Although prices in Mexico were lower in the late 1980s, particularly for heavy fuel oil and gasoline, by the end of the 1990s, they have, in general, surpassed those in the US. Although real prices for natural gas are currently lower in the US, Mexican prices have fallen precipitously since 1966 — a trend that is expected to continue. Therefore, one could expect the consumption of natural gas to keep increasing.

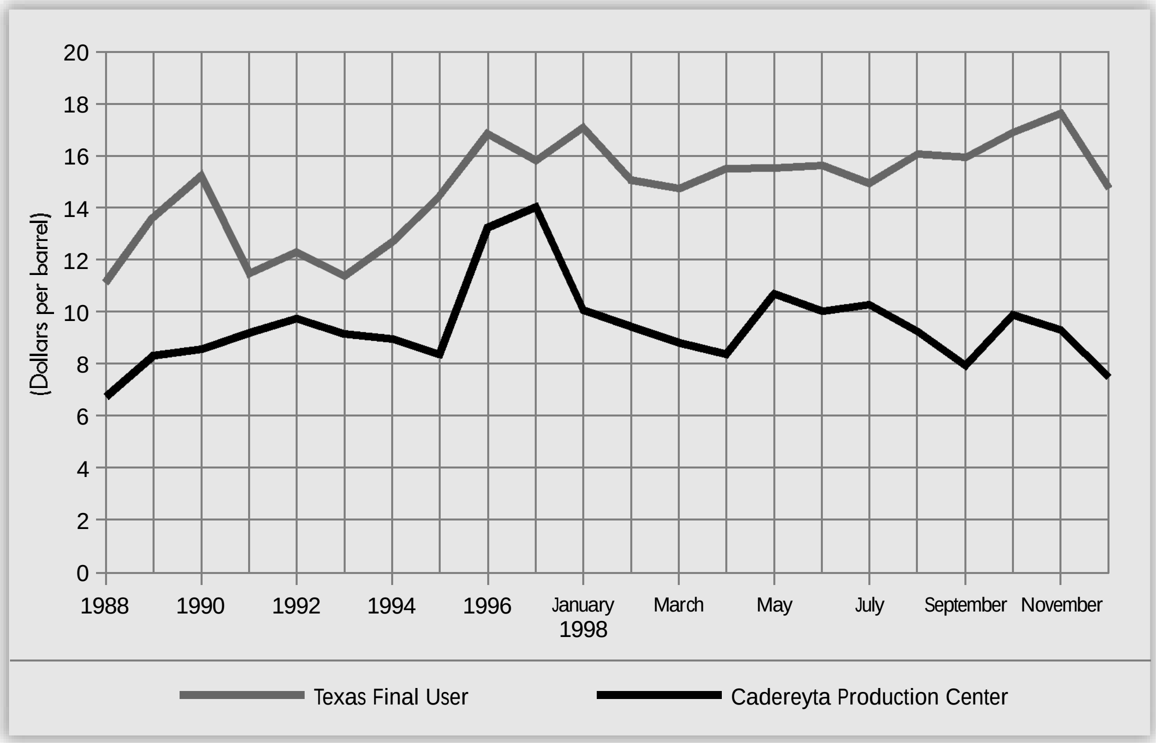
Table 6 shows estimated CO_2 emission savings

TABLE 6: Estimated CO_2 Emission Savings from Recent Fuel Price Changes

	1988 emissions (in teragrams)	1996 emissions (in teragrams)	Real price change (final price as % of original)	Time interval	Elasticity demand	Emission reduction (%)	Emission reduction (in teragrams)
Gasoline	46.55	64.87	52.21	1988-1996	0.70	6	96.99
Heavy fuel oil	21.07	18.65	96.75	1988-1996	0.70	4.5	46.35

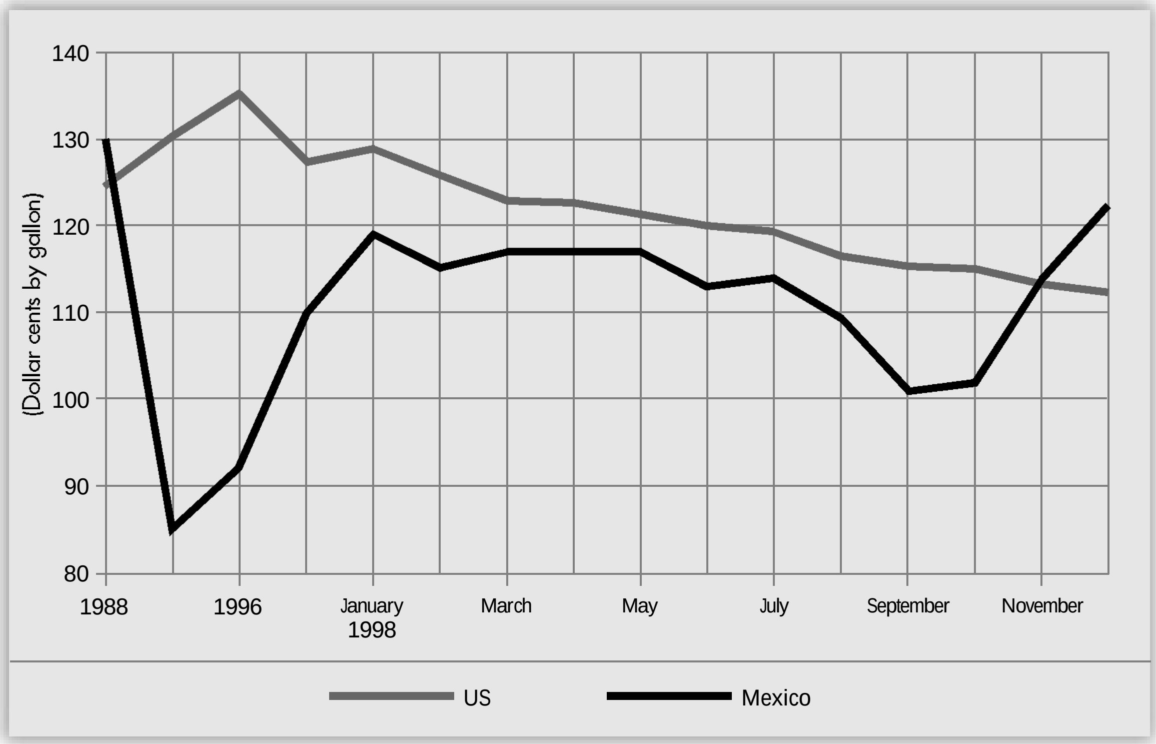
Source: Data from SEMARNAP, Subsecretaría de Planeación, *Estimaciones de la reducción de CO_2 por el aumento en precios de Combustibles,* Internal Document, 1999.

FIGURE 7.1: Real Price of Heavy Fuel Oil — Mexico and US



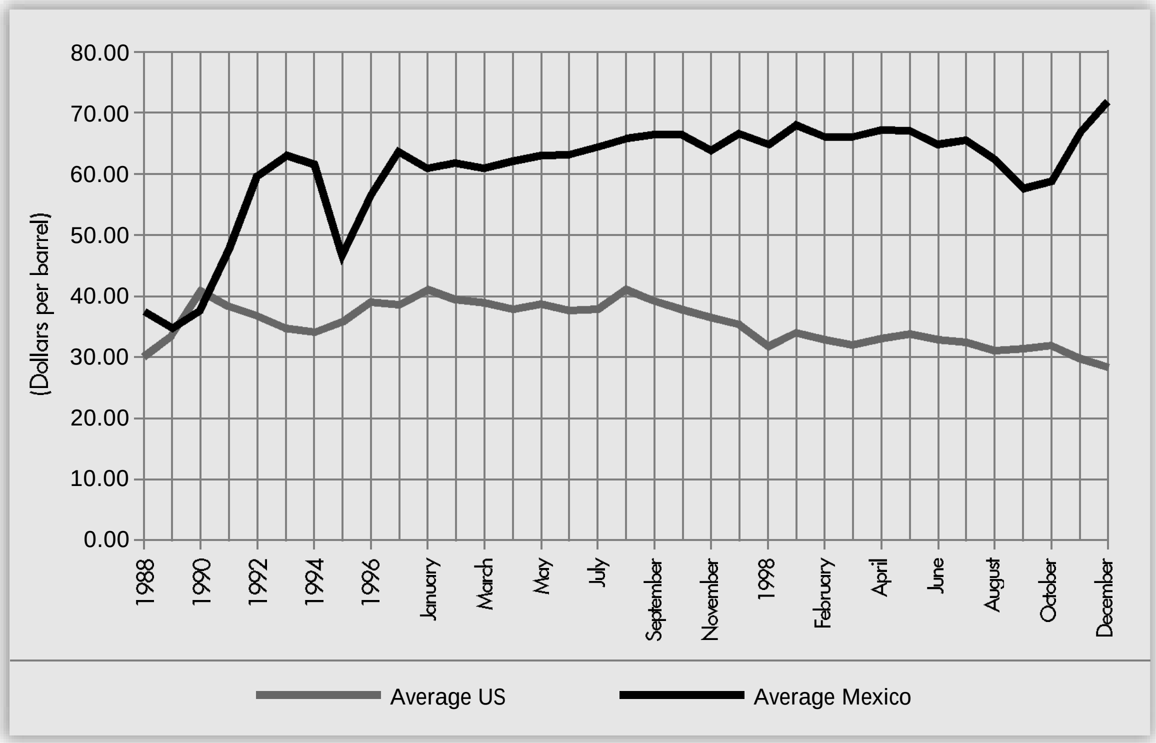
Source: PEMEX, Precios de Ref. Internationales; January 1999.

FIGURE 7.2: Real Price of Diesel — Mexico and US



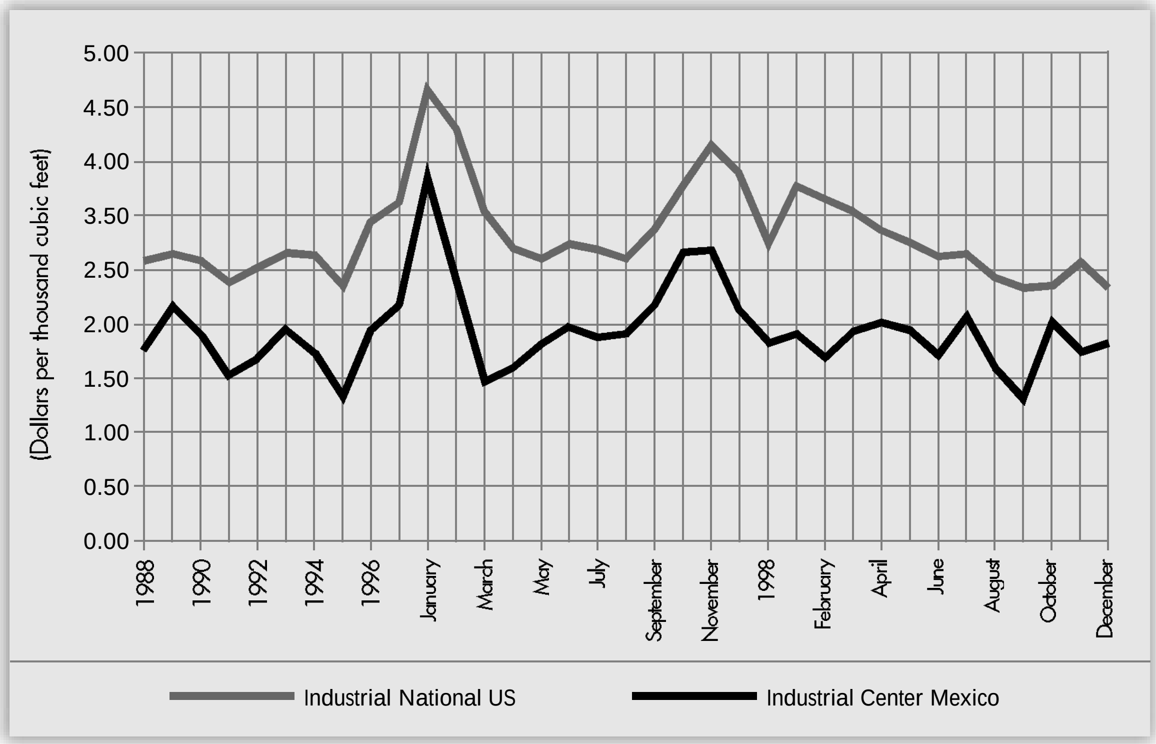
Source: PEMEX, Precios de Ref. Internationales; January 1999.

FIGURE 7.3: Real Price of Unleaded Gasoline — Mexico and US



Source: PEMEX, Gerencia de Precios, Dirección Corporativa de Finanzas. Precios de Referencia Internacionales.

FIGURE 7.4: Real Price of Natural Gas — Mexico and US



Source: PEMEX, Gerencia de Precios, Dirección Corporativa de Finanzas.

TABLE 7.1: Projected Effect of a Tax on the Demand of Gasoline

Tax rate	10%	25%	50%
Price elasticity	**Change in demand**		
–0.55 (Pindyck, 1979)	–5.5%	–13.8%	–27.5%
–0.799 (Eskeland and Feyzioglu, 1994)	–8.0%	–20.0%	–40.0%
–0.96 (Brandt and Botero, 1985)	–9.6%	–24.0%	–48.0%
–1.0 (Sterner, 1990)	–10.0%	–25.0%	–50.0%

The values reported by Eskeland and Feyzioglu, as well as those given by Brandt and Botero, are specific to Mexico; the others were calculated for all developing countries.

Source: Eskeland & Feyzioglu, 1994.

TABLE 7.2: Projected Reductions in Carbon Emissions from Tax Increases

Tax rate	0%	10%	25%	50%
Gasoline consumption (thousands of barrels/day)	501.0*	460.9	400.8	300.6
Carbon emission (thousands of m^3/day)	70.8	61.1	56.6	42.5

* Total consumption of gasoline in 1994 (PEMEX, 1995).

Source: Estimates of Unidad de Análisis Económico y Social.

Equivalences: 6.3 barrels =1 cubic metre (PEMEX)=carbon emissions of 0.89 m^3/toe. OECD, 1993.

resulting from recent fuel price changes from 1988 to 1996, based on a demand elasticity of 0.70. As Table 6 demonstrates, real price changes are significant, for gasoline (52.21%) and for heavy fuel oil (96.75%).

Gasoline prices in Mexico are increasing more than in the US (as seen in Figure 7.3). However, they still do not cover all production and consumption costs. Altering the price through taxes can internalise such costs and benefits. A tax on gasoline could achieve four objectives: rationalise consumption, internalise cost of pollutants, increase funds available to states and municipalities for environmental clean-up and transport improvement, and decrease other taxes.

In this context, effects of a tax on gasoline — an attractive instrument to promote a decrease in consumption — have been calculated. Several studies have estimated the price elasticity (defined as a percent variation in the demand when 1% change occurs in the price of the commodity [Kreps, 1990]) for the demand for gasoline. Table 7.1 shows long-term price elasticities in gasoline demand to taxes of 10%, 25%, and 50% (Eskeland and Feyzioglu, 1994). Table 7.2 shows the corresponding carbon emissions. In order to estimate the reductions in carbon emissions, total gasoline consumption was multiplied by the gasoline's carbon emission factor.

FOREST CONSERVATION POLICIES

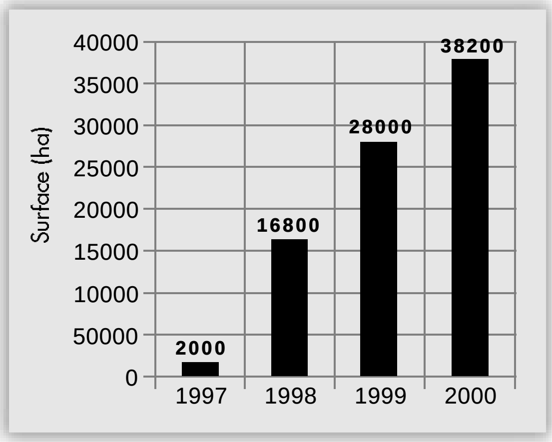
Approximately 29% of Mexico is forested, and another 43% is covered by natural vegetation. Changes in land use and forestry activities are responsible for 30.56% of Mexico's total CO_2 emissions, the largest share of any sector. Several conservation and reforestation policies, programmes, and projects have been devised to stop the degradation of these lands or to enhance their productive capacity.

These programmes not only contribute to the restoration of degraded lands but also help to protect Mexico's biodiversity. Although Mexico is considered as one of the 11 "megadiverse" countries that represent 65% of the earth's total biodiversity, natural resources suffer from long-term degradation. Land use practises are inadequate, slash-and-burn agriculture continues, and salinisation affects up to 8000 km^2 of land. Depletion of natural resources is accelerating: 600,000 ha are deforested annually, and water and air pollution have become crucial issues.

Owing to legal and land tenure limitations, Mexico was not able to develop extensive commercial tree plantations before 1992. In that year, however, Article 27 of the Constitution, as well as the Agrarian and Forestry Law, was modified, and new prospects presented themselves. These changes permit the association of investors and landowners for industrial forestry.

Thus, Mexico has been channelling resources towards the improvement of forest management. The National Reforestation Program (PRONARE) was created in an attempt to restore degraded areas. It aims to increase the vegetation coverage and restore degraded ecosystems by introducing appropriate species. The main targets for 1998 were to reforest 200,000 ha to produce 285 million plants, and to collect 25 tons of seeds (SEMARNAP, PRONARE, 1998, p. 10). The whole process includes forestry germ plasm banks, plant production, reforestation, maintenance, and evaluation.

FIGURE 8: Surface to be Reached with PRODEPLAN Support, 1997-2000



Source: *Programa de Trabajo,* SEMARNAP, 1998, p. 55.

What has PRONARE achieved so far? Between 1995 and 1997, 800 million plants were produced in all the national nurseries; an amount unprecedented in this country's history. Sowing practices have benefitted approximately half a million hectares. Plant production has increased tremendously because of improved financial support.

Additionally, the Program for the Development of Commercial Forestry Plantations (PRODEPLAN) is an incentive mechanism that aims at introducing a sustainable model for commercial forestry plantations. SEMARNAP may provide up to 65% of the investment costs of an approved project. As a consequence of this programme, 875,000 ha will be planted in the next 25 years. For 1997, approximately US$25 million was allocated to this end.

During its first phase, PRODEPLAN granted subsidies to 13 projects to establish 48,000 ha of commercial forestry plantations for 1997 to 2003. For the first time, forestry plantations receive direct federal government support. Although most of the resources are earmarked for large projects, several small projects, implemented by social organisations, will also receive support. Between September 1997 and September 1998, woody production reached 8.3 million cubic metres of raw logs — 13.7% more than the previous year. Non-woody production increased to 92,000 tons in the period, a 20% increase.

Like PRODEPLAN, the Program for Forestry Development (PRODEFOR) works in the forestry sector, but with a focus on native forests and the people who live in them. Therefore, its aim is to conserve native forests as a life option, by increasing production and productivity (from lumber as well as from the harvesting of non-timber resources such as fruits and nuts) through sustainable forestry management (SEMARNAP, *Programa de Trabajo,* 1998). Initially modest in scope, it is nevertheless the first programme of its type established by the Government of Mexico, and is expected to provide a range of indirect environmental services, such as biodiversity conservation, water capture, soil retention, and recreational options.

PRODEFOR was initiated on 15 August 1997 with a budget of US$2.3 million, which was tripled for 1998. During its first year, only 200 ha were covered. In 1998, this surface increased dramatically to 16,800 ha, and by the year 2000 that number will more than double. Under the plan, an estimated 1.8 million ha will be available for timber harvesting. Also, 300,000 ha will be managed for the sustainable use of non-woody resources. In 1998, priority was given to small producers, and to those that did not receive subsidies in 1997. Figure 8 shows the areas covered through PRODEPLAN.

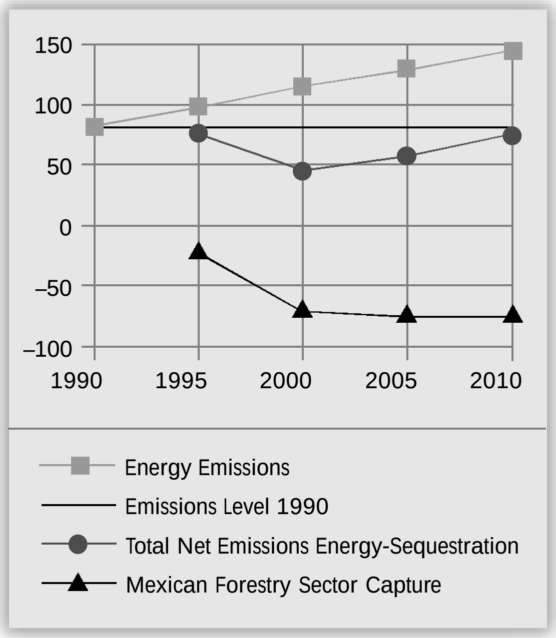
Because of extreme weather,[5] some of it attributed to meteorological phenomena such as El Niño and La Niña, the incidence of fires increased dramatically in 1998. Between January and July 15, 1998, an abnormally high number of fires were reported: 14,136 fires affecting 540,859 ha. Many parts of the country were hit, but the most severely affected states were Chiapas, Durango, Oaxaca, San Luís Potosí, México, Michoacán, and Puebla. Fires were caused mainly by slash-and-burn activities (47.1%), followed by fires set by forest users (19.8%) (CONAF, 1998). According to the latest evaluation, 42.3% (229,625 ha) of burned area was grasslands, 31.9% (172,563 ha) shrubs and thickets, and 25.7% (139,271 ha) wooded areas.

Ninety percent of the fires were controlled in less than 24 hours, and reversing the damage from the burning to natural vegetation, especially to forests, is a priority. PRONARE is a key player in this; its Programme for the Restoration of Areas Affected by Fires aims to reforest a minimum of 50,700 ha of affected wooded areas.

The value of carbon storage — which can be enhanced through forest conservation, afforestation, and other land management regimes, such as agroforestry — provides an additional economic rationale for preserving forest resources. The cost of carbon sequestration by forestry activities and other land management processes compares favorably with many engineering solutions to curtail CO_2 emissions, such as energy savings programmes (Dixon et al., 1993, and IEA, 1998b, p. 3).

Although energy emissions are likely to increase, as seen in Figure 9, net emissions (emissions minus uptake) from 1990 to 2010 could stay below the 1990 emission level, owing to carbon sequestration. However, the Government of Mexico is more cautious in its predictions. It projects that, starting in 2010, the negative causes of deforestation will be under control, and that from 2010 on, these sorts of carbon sequestration schemes will become potential alternatives. Although these projections are somewhat speculative, it is clear that the forestry sector could become an important player in developing renewable energy and in climate change mitigation.

FIGURE 9: Energy Sector Emissions vs. Forestry Capture, 1990-2010 (MtonC)



Source: Masera, O. 1995: *Future GHG Emissions and Sequestration Scenarios from Land Use Changes in Mexico.*

For instance, after investigating carbon sequestration by large-scale forestry in Chiapas, the IEA concluded that “given an appropriate mechanism for distributing sequestration rents to landowners, the supply of carbon sequestered would rise sharply at incentive levels of 5-15 $US/tC.” Thus, according to the study, “A large-scale incentive based sequestration programme could have significant benefits for biodiversity conservation, income generation and long term economic viability for the regions concerned” (IEA, 1998b, p. 74).

---

[5] *For example, temperatures reached* 35^{0}*C and in extreme cases* 49^{0}*C, winds bypassed normal patterns and reached speeds of 100 km/hr, and humidity levels reached below 30%.*

Recent large-scale schemes for sequestering carbon in the biomass of forests are starting to shed light on future opportunities. For example, a project situated in two regions — highland Mayan Tojolobal and lowland Mayan Tzeltal communities in Chiapas — is encouraging companies or individuals to purchase "proto-carbon credits" from a local Trust Fund in order to offset GHG emissions. The Trust may provide farmers with up to 25 years' financial and technical assistance for farm and community-scale forestry and agroforestry activities.

URBAN POLICIES

Because of Mexico City's size and the seriousness of its air pollution problem, which includes significant emissions of several GHGs,[6] a discussion of how the government is responding to this issue is relevant to this report. The transport sector represents the heaviest contributor to emissions in the Mexico City Metropolitan Zone (ZMVM). An emissions inventory showed that the transport sector contributed 75% of the total emissions of gases and particulate matter (4,009,625 tons/year) in the ZMVM in 1994. Vehicles emitted 71% of NO_X, 99% of CO, 54% of HC, and 27% of SO_2. An estimated 2.5-3 million vehicles circulate in Mexico City, a number that has been increasing by about 10% annually (Dep. Del Distrito et al., 1996, p. 84). Table 8 breaks down the share by sector. Since CO_2 emissions have not yet been quantified, they are not included.

Steps to address air pollution problems include setting environmental standards and emission limits, improving fuel quality, strengthening vehicle standards and emission requirements, and integrating environmental and transport policies. The most ambitious and sound example is the 1995-2000 Air Quality Improvement Program for the Mexico City Valley (PROAIRE).[7] Other programmes have been devised for the largest and most industrialised zones, such as Mexico City, Guadalajara, Monterrey, Ciudad Juárez, and Toluca. PROAIRE pursues four policy goals: 1) promoting clean industry, 2) switching to cleaner fuels, 3) upgrading and improving mass transport, and 4) promoting an environmentally sensitive urban order (see Table 9). Additionally, in order to detect dangerous levels of pollutants, cities with more than 500,000 inhabitants have been strongly advised by the INE to set up monitoring stations (Government of Mexico, 1997, p. 63). One of the central components of PROAIRE's next phase will be the quantification of GHG emission reductions.

All of these steps, including PROAIRE's four goals, are expected to yield many benefits. For example, through the clean industry goal, 252,525 tons of hydrocarbons are expected to be reduced

TABLE 8: Emissions Inventory, 1994 (tons/year)

Sector (tons/year)	PST*	SO_2	CO	NO_X	HC	Total	%
Industry	6358	26,051	8696	31,520	33,099	**105,724**	**3**
Services	1077	7217	948	5339	398,433	**413,014**	**10**
Transport	18,842	12,200	2,348,497	91,787	555,319	**3,026,645**	**75**
Vegetation/land	425,337	0	0	0	38,909	**464,246**	**12**
Total	**451,614**	**45,468**	**2,358,141**	**128,646**	**1,025,760**	**4,009,629**	**100**

*Total suspended particulates.

Source: *The 1995-2000 Air Quality Improvement Program for the Mexico City Valley,* 1996, p. 74.

---

[6] *Gases such as CO and NO_X are considered GHGs, and HC is one of its precursors.*

[7] *PROAIRE has not yet contemplated how much reduction of GHG emissions will be generated with the reduction of other pollutants, such as SO_2, NO_X, TSP, CO, and HC. From 1999 onwards, evaluations will be made to determine whether PROAIRE's strategies have reduced the emissions of pollutants that indirectly will also reduce levels of GHG emissions.*

TABLE 9: The 1995-2000 Air Quality Improvement Program for the Mexico City Valley

Goals	Strategies	Emission Reduction					
			NO_X	HC	SO_2	CO	PST
I. Clean industry	• Improvement and incorporation of new technologies in the industry and services sector • Improvement and substitution of industrial energies • Economic incentives • Industrial inspection and vigilance • Environmental education and information, and social participation	Emission reduction (tons/year)	17,700	252,525	14,460	270	2,220
		Reduction with respect to the sector (%)	48.0	48.5	43.5	2.8	29.9
		Reduction with respect to the total (%)	13.8	24.6	31.8	0.01	0.5
II.Clean vehicles	• Imrovement and incorporation of new technologies in vehicles • Improvement and substitution of vehicle energies • Economic incentives • Industrial inspection and vigilance • Environmental education and information, and social participation	Emission reduction (tons/year)	30,221	223,700	6,801	1,433,331	5,214
		Reduction with respect to the sector (%)	32.9	40.3	56.0	60.9	27.7
		Reduction with respect to the total (%)	23.5	21.8	15.0	60.8	1.2
III. Efficient transport and new urban order	• Ample supply of efficient and safe public transport • Integration of metropolitan policies (urban development, transport, and ecology) • Economic incentives • Industrial inspection and vigilance • Environmental education and information, and social participation	Emission reduction (tons/year)	5,656	40,598	773	193,219	500
		Reduction with respect to the sector (%)	6.2	7.3	6.4	8.2	2.7
		Reduction with respect to the total (%)	4.4	4.0	1.7	8.2	0.1
IV.Eco-logical regulation	• Integration of metropolitan policies (urban development, transport, and ecology) • Environmental education and information, and social participation	Emission reduction (tons/year)	NA	NA	NA	NA	195,630
		Reduction with respect to the sector (%)	NA	NA	NA	NA	46

annually, and through the clean vehicle goal, another 1,433,331 tons of CO emissions will be cut (see Table 9). Because PROAIRE was not launched until 1996, it is too early to quantify its successes. For many strategies, the actual implementation phase did not start until 1997. Authorities claim that the air deterioration process has been slowed; however, the present level of stabilisation is still unsatisfactory. Clearly, combatting air pollution in Mexico City remains a challenge.

FUTURE EMISSIONS

In order for Mexico to achieve a standard of living comparable to that of a developed country, it will have to grow at an accelerated pace in the coming years. In most macroeconomic projections, the total use of energy will also have to increase as either the cause or the effect of economic improvement. The need for increased energy consumption is clear; the question is how efficiently this energy will be used and how it will be supplied. Three scenarios are possible. The first and simplest is to extrapolate current energy intensity into the future. The second — based on the idea that with improved economic performance, average Mexicans will demand more goods and services — will mean an increase in energy intensity. The third scenario would show energy intensities decreasing as a result of an accelerated adoption of more efficient technologies.

Which of these scenarios is the most likely to materialise is a more difficult question to answer without a formal analysis. Although total energy use is expected to rise in any case, it is likely that some sectors of the economy will show increases. In others, technology and good practises may reduce energy demand. So far there has been a persistent attempt to understand the correlation between the energy sector and the rest of the economy in the developed world. However, the relationship has not been analysed comprehensively. As a result, it is impossible to provide definite answers on what the trend in energy consumption will be and how it will be driven by economic growth and demographic pressures.

CONCLUSIONS

Table 10 shows the available estimates on emission reductions based on many of Mexico's policies and programmes. The most salient policy changes that are slowing GHG emissions are grouped as follows: energy sector restructuring through the promotion of renewable energies and improvements in the efficiency of energy that include the Integrated Fuel Policy; forest conservation programmes that include PRONARE, PRODEPLAN, and PRODEFOR; urban policies that include PROAIRE; and price reforms.

Summing up, Mexico's structural and political reforms have fostered policies and programmes that seek environmental, economic, energy efficiency and health benefits, or traffic congestion relief. In addition to these steps, and in response to its UNFCCC commitments, Mexico has produced the Climate Change Country Study and completed mitigation and adaptation studies. The federal government established an Inter-ministerial Committee in charge of co-ordinating all issues that relate to climate change. Together, these developments have set in motion a process that, as a beneficial side effect, will continue reducing the rate of growth of carbon emissions. Thus, although Mexico is not seeking to directly reduce GHG emissions through mechanisms such as a baseline for growth, it could eventually accomplish that through these means.

The sum of these steps represents the cornerstone of Mexico's commitments. Among the different approaches being suggested at the international level, Mexico remains open to the possibilities afforded by the Clean Development Mechanism, and will remain attentive to the way in which these develop in the near future. Given this analysis, however, it is still rather difficult for Mexico to adopt a baseline for growth and take on voluntary commitments.

TABLE 10: Summary Table

Policy or program	Estimated total CO_2 emission reduction (if not available, other GHG or/and precursor gases)
Fuel substitution	SO_X (reduction for 2005) = 51% NO_X (reduction for 2005) = 49% Carbon (reduction for 2005) = 3%
Hydroelectric plants	From 1993 to 1997 = 8,556,896.33 tons of CO_2
Daylight savings	From 1996 to 1998 = 1,618,646.34 tons of CO_2
PROAIRE	HC (tons/year) = 516,823 CO (tons/year) = 1,626,820 PST (tons/year) = 203,564
Price reforms	From 1988 to1996 = 220,000.29 tons/toe of CO_2

ACKNOWLEDGEMENTS

The authors would like to thank external peer reviewers, including Hugo Contreras, Dr. Carlos Gay, and Dr. Fernando Tudela, for comments on earlier drafts of this publication. In particular, we are grateful to Julia Martínez for encouragement during the writing of this document, especially for comments on earlier drafts as well as for assistance with obtaining useful information and data. Finally, we would like to thank Moises Orozco for assistance obtaining useful information, and Rebeca Azaola for assistance with the production of figures.

The authors take full responsibility for the content of this document. All interpretations and findings set forth in this document are those of the authors and not of the institutions to which they belong.

REFERENCES

Belausteguigoitia, J. C. and Ibarrarán, Nov.-Dec. 1995: Economical instruments for the reduction of greenhouse gas emissions: the case of Mexico. Interciencia, **20** (6).

Brandt and Botero, 1992: Energy demand in the transport sector of Mexico. Journal of Development Economics, **17**.

Comisión Nacional para el Ahorro de Energía, Secretaría de Energía, 1998: Informe Ejecutivo, 1996-1997 (Primer borrador), Mexico City.

Consejo Técnico Consultivo Nacional Forestal (CONAF), June 3, 1998: Programa de Reforestación de Aréas Forestales Afectadas por Incendios. Document presented at the XXXIII CONAF Ordinary Session, Mexico City.

Departamento del Distrito Federal, Gobierno del Estado, and SEMARNAP, 1996: Programa para Mejorar la Calidad del Aire en el Valle de México, 1995-2000. Mexico City.

Dixon, R.K., K.J. Andrasko, F.G. Sussman, M.A. Lavison, M.C. Trexler, and T.S. Vinson, 1993: Forest sector carbon offset projects: near-term opportunities to mitigate GHG emissions. Water, Air, and Soil Pollution, **70**.

Eskeland, G., 1992: A Presumptive Pigouvian Tax on Gasoline: Analysis of an Air Pollution Control Program for Mexico City. The World Bank, mimeograph. Washington, DC.

Eskeland, G., and Feyzioglu. Is Demand for Polluting Goods Manageable? An Economic Study of Car Ownership and Use in Mexico. Policy Research Working Paper #1309. The World Bank. Washington, DC.

Fernández, A., L. Rubio, and C. Sales, 1995: México Tiempo de Cambio. Editorial Cal y Arena, Mexico City.

Fideicomiso para el Ahorro de Energía Electrica, 1997: Informe de Labores 1997, Mexico City.

Gobierno de México, 1997: México: Primera Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático. Mexico City.

Grupo de Políticas de Combustibles, Sept. 14, 1995: Resultados de los Temas Abordados por el GPC en el Periodo Marzo-Agosto de 1995. Mexico City.

Instituto Nacional de Ecología, 1994: Estudio de Costo Beneficio. Norma Oficial 058, Mexico City.

Instituto Nacional de Ecología, 6 February 1998: Presidente del INE. Lineamientos para una Política de Energía y Cambio Climático. Internal document, preliminary version.

International Energy Agency, 1998a: Energy balances of OECD countries, 1960-1996.

International Energy Agency, February 1998b: GHG Research and Development Programme, Assessment of the Cost of Large Scale Forestry for CO_2 Sequestration. Report number PH2/15.

Kreps, D., 1990: A Course on Microeconomic Theory. Princeton University Press, Princeton, N.J.

McKinsey and Company, Inc., 1990: Developing Fuels Policy for Mexico.

Pindyck, R., 1979: The Structure of the World Energy Demand. MIT Press, Cambridge, Mass.

Secretaría de Energía, 1998a: Subsecretaría de Políticas y Desarrollo de Energéticos, Dirección General de Política y Desarrollo Energético, Climate Change and the Energy Sector. Internal document. Mexico City.

Secretaría de Energía, 1998b: Acciones para Promover la Cogeneración (documento de Prospectiva del Sector Energía). Internal document. Mexico City.

Secretaría de Energía, 1998c: Subsecretaría de Políticas y Desarrollo de Energéticos, Dirección General de Políticas y Desarrollo Energético. Principales Políticas Energéticas Enfocadas a la Disminución de las Emisiones de Gas Efecto Invernadero (1993-1998). Internal document. Mexico City.

Secretaría de Energía, 1998d: Subsecretaría de Políticas y Desarrollo de Energéticos, Dirección General de Políticas y Desarrollo Energético. Substitución de Combustoleo por Gas Natural. Internal document. Mexico City.

Secretaría de Energía, 1996: Balance Nacional de Energía. Mexico City.

SEMARNAP, 1998: Programa de Trabajo, 1998. Litografía Eros S.A. de C.V. Mexico City.

SEMARNAP, Subsecretaría de Recursos Naturales. Dirección General Forestal, PRODEPLAN. Internal document. Mexico City.

SEMARNAP, 1998: Subsecretaría de Recursos Naturales. Pograma Nacional de Reforestación (PRONARE). Internal document. Mexico City.

Shelling, T., 1998: Costs and Benefits of Greenhouse Reduction. AEI Press, Washington, DC.

Sterner, T., 1990: The Pricing and Demand for Gasoline. Swedish Transport Research Board, Stockholm, Sweden.

UNDP, 1997: Energy after Rio: Prospects and Challenges. UNDP, Energy 21, and Stockholm Environment Institute, New York.

CHAPTER 3

Is China taking actions to limit its greenhouse gas emissions? Past evidence and future prospects

ZhongXiang Zhang
Faculty of Economics
and Faculty of Law
University of Groningen
The Netherlands

SUMMARY: As the world's second largest carbon emitter and home to more than one-fifth of the world's population, China is a key player in global efforts to mitigate climate change. In this article, we first examine the historical evolution of China's CO_2 emissions during the period 1980-1997. By analysing the historical contributions of inter-fuel switching, energy conservation, economic growth and population expansion to CO_2 emissions, we show that China has made significant contributions to reducing global CO_2 emissions even though none of these carbon savings resulted from specific climate mitigation policies. Without the policies and measures undertaken since 1980, China's CO_2 emissions in 1997 would likely have been 50% higher than they actually were. The chapter also analyses the economic effects would be if China's carbon emissions in 2010 were cut by 20% and 30%, relative to the baseline. We found that China's GNP losses under the two less restrictive carbon limits are in the same range as the often reported estimates for industrialised countries under restrictive carbon limits. Then we envision some win-win strategies that could be reasonably expected from China while its per capita income catches up with the level of middle-developed countries, including a continued emphasis on energy conservation and efficiency.

DECOUPLING CARBON EMISSIONS INCREASES FROM ECONOMIC GROWTH, 1980-1997

With more than 1.2 billion people, China is home to about 21.5% of the world's population (see Table 1) and has a large and rapidly growing economy, making the country an important player on the world's stage. Since launching its open-door policy and economic reform in late 1978, China has experienced spectacular economic growth, with its gross domestic product growing at an average annual rate of about 10% over the period 1978-1997. Along with the rapid economic development, energy consumption rose from 571.4 million tons of coal equivalent (Mtce) in 1978 to 1440.0 Mtce in 1997. Currently, China consumes almost 1400 million tons of coal a year, leading the world in both production and consumption of coal. As indicated in Figure 1, coal has accounted for about 75% of the total energy consumption over the years. This share has remained stable after having increased from 70% in 1976, indicating that coal has fuelled much of China's economic growth over the past

TABLE 1: Global CO_2 Emissions Compared to Population in 1996

Country	Share of global CO_2 emissions (%)	Share of the world population (%)
USA	25.0	4.7
EU-15	14.7	6.5
China	13.5	21.5
CIS Republics	10.2	5.0
Japan	5.6	2.2
India	3.6	16.3
Canada	2.1	0.5
Australia	1.3	0.3

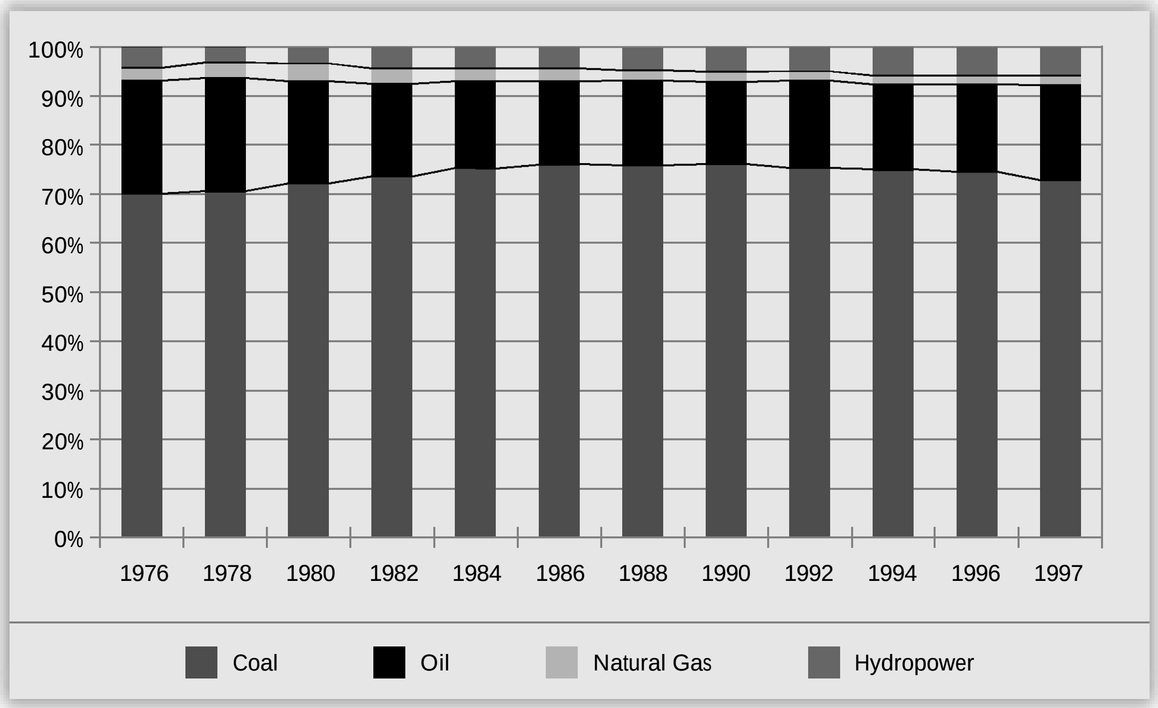
Source: Jefferson (1997)

two decades. Although China had surpassed Russia to become the world's second largest energy producer and user in 1993, China's current per capita energy consumption of 1.165 tce (see Appendix) is about half the world's average, or only about one-twelfth of that of the US.

Accompanying the growth in fossil fuel use, China's CO_2 emissions have grown rapidly. The corresponding CO_2 emissions from fossil fuels in China over the period 1980-97 have been calculated on the basis of fossil fuel consumption and by using the CO_2 emission coefficients given in Table 2, which are measured in tons of carbon per ton of coal equivalent (tC/tce) and are generally considered suitable for China. The total CO_2 emissions in China rose from 358.60 million tons of carbon (MtC) in 1980 to 847.25 MtC in 1997, with an average annual growth rate of 5.2%. Thus, China ranks as the world's second largest CO_2 emitter, behind only the US. But on a per capita basis, China's CO_2 emissions of 0.685 tC in 1997 (see Appendix) were very low — only about half the world average. Moreover, as Figures 2a and 2b show, both energy intensity (E/GDP) and carbon intensity (CO_2 emissions/GDP) have declined significantly during this period.

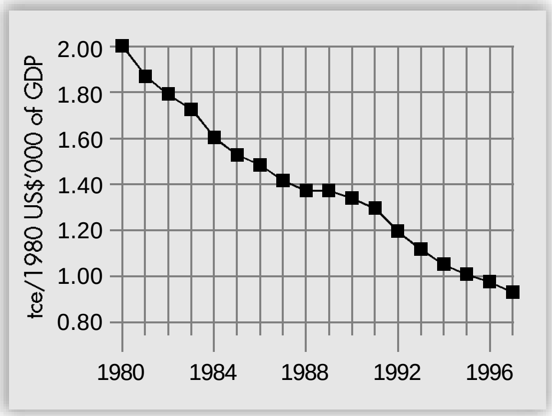
The breakdown of CO_2 emissions by fuel is shown in Figure 3. Because of the coal-dominant structure of Chinese energy consumption, it is not surprising that coal predominates, accounting for 81.3% of total emissions in 1997. This share has remained

FIGURE 1: Composition of Energy Consumption in China, 1976-1997



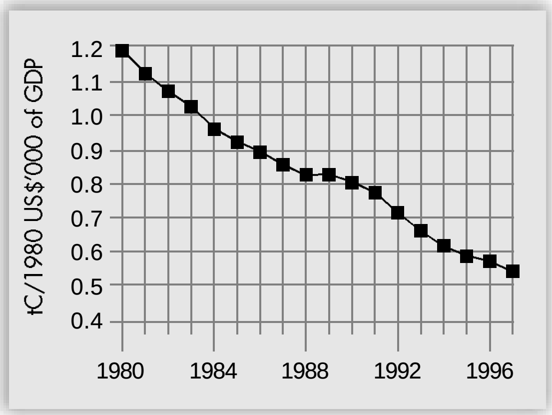
Sources: Based on data from the State Statistical Bureau (1992, 1998).

FIGURE 2a: Energy Intensity of GDP in China, 1980-1997



Source: See Appendix.

FIGURE 2b: Carbon Intensity of GDP in China, 1980-1997



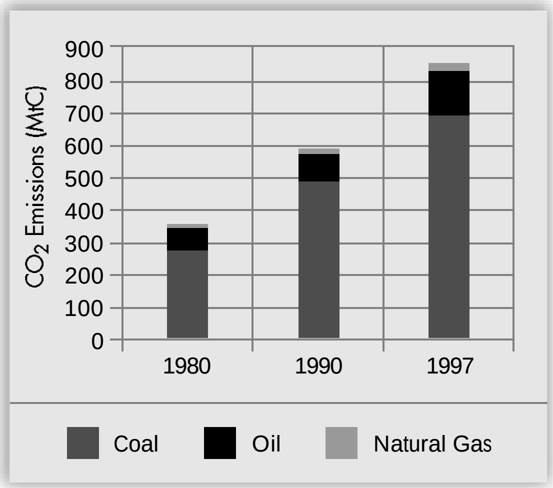
Source: See Appendix.

TABLE 2: CO_2 Emission Coefficients for China

Fuels	tC / tce
Coal	0.651
Oil	0.543
Natural gas	0.404
Hydropower, nuclear power and renewables	0

Source: Energy Research Institute (1991).

FIGURE 3: China's CO_2 Emissions by Fuel



Source: See Appendix.

almost unchanged over the past two decades.

Let us now turn to the contributions of inter-fuel switching, energy conservation, economic growth and population expansion to CO_2 emissions over the past 17 years.

CO_2 emissions can be decomposed as follows[1]:

$$C = \left(\frac{C}{FEC}\right)\cdot\left(\frac{FEC}{TEC}\right)\cdot\left(\frac{TEC}{GDP}\right)\cdot\left(\frac{GDP}{POP}\right)\cdot POP$$

where C is the amount of CO_2 emissions, FEC is the total carbon-based fossil fuel consumption, TEC is the total commercial energy consumption, GDP is the Gross Domestic Product, and POP is the population.

Taking logs and differences over time yields:

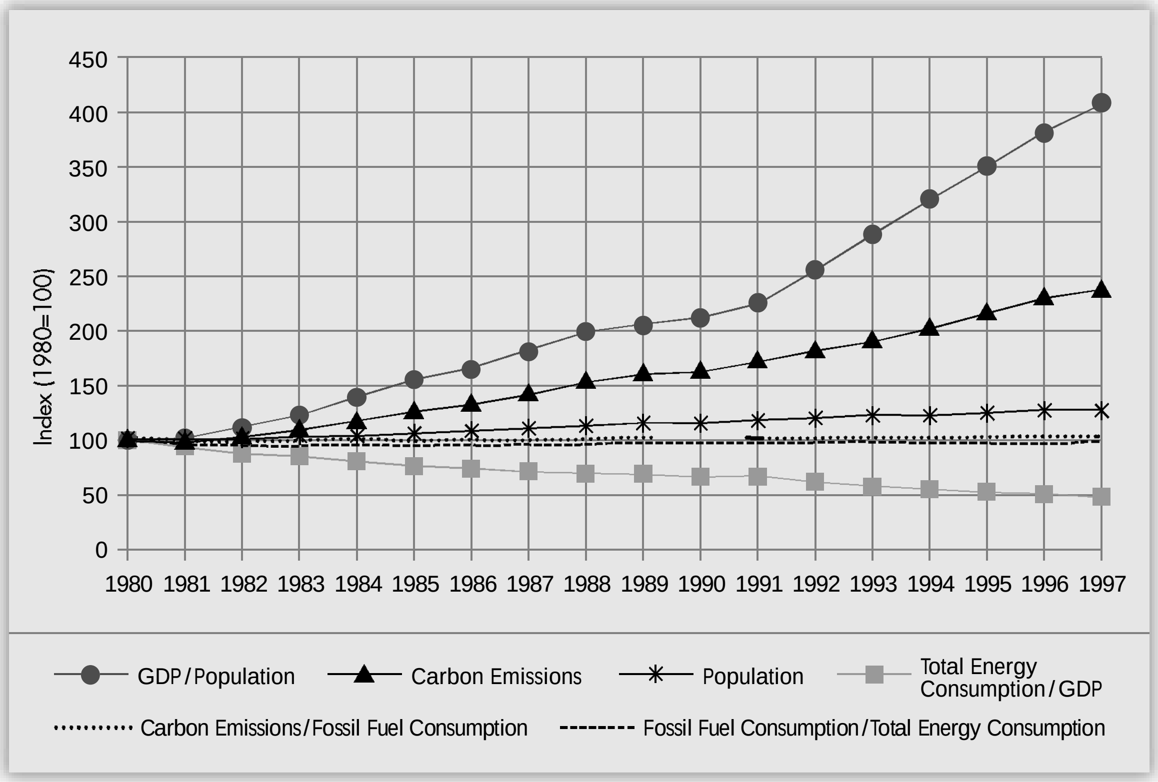
$$\Delta\log C = \Delta\log(C/FEC) + \Delta\log(FEC/TEC) + \Delta\log(TEC/GDP) + \Delta\log(GDP/POP) + \Delta\log(POP)$$

The first term on the right-hand side of the equation shows the effect of changes in the

---

[1] *This is a concrete form of the so-called Ehrlich equation, I = PAT, where I represents the adverse environmental impact, P is the population, A is the consumption per capita, and T is the amount of resources required by environmentally damaging technology for producing 1 unit of consumption (Ehrlich and Ehrlich, 1990). It is used as a proxy for a determinant of environmental impact.*

FIGURE 4: Contribution to CO_2 Emissions in China, 1980-1997



Source: See Appendix.

composition of carbon-based fossil fuels on emissions, and the second term indicates the contribution of carbon-free fuels (1-FEC/TEC) to a reduction in emissions. (If the share of carbon-free fuels [1-FEC/TEC] is increased, the CO_2 emissions can be effectively reduced.) These two terms therefore capture the contribution of inter-fuel substitution to the changes in emissions, as explained below: fuels vary considerably in their relative CO_2 emissions. Specific CO_2 emission from coal burning is 1.6 times that from natural gas and 1.2 times that from oil (see Table 2). Hydropower, nuclear energy and renewables do not produce CO_2 emissions. In this regard, increased use of carbon free energy sources, along with substitution of natural gas for the more pollution-producing coal and oil, would clearly reduce CO_2 emissions. The third term shows the effect of changes in the aggregate energy intensity on emissions, and the last two terms show the effect on emissions caused by growth in income per capita and population, respectively. Needless to say, this equation is in a form suitable for analysing the historical contributions of inter-fuel switching, energy conservation, economic growth, and population expansion to CO_2 emissions by

TABLE 4: Contributions to CO_2 Emissions Growth, 1980-1997 (MtC)[a]

Due to change in fossil fuel carbon intensity	Due to penetration of carbon free fuel	Due to change in energy intensity	Due to economic growth	Due to population expansion	Total change in CO_2 emissions
+3.93	–10.48	–432.32	+799.13	+128.39	**+488.65**

[a] A positive sign indicates an increase; a negative sign indicates a decline.

Source: Author's calculations.

examining the relevant time-series data. Table 4 shows the results of this analysis for the period 1980-1997, based on data given in the Appendix to this chapter, which quantifies the historical contribution to CO_2 emissions each factor has made. The corresponding CO_2 emissions associated with the fossil fuel consumption have been calculated above. Some of these data are presented in Figure 4, after normalisation to the year 1980.

The results in Table 4 and Figure 4 clearly indicate the relative importance of each factor in terms of its contribution to CO_2 emissions growth. Given that China has been the most rapidly expanding economy over the past 17 years, it is not surprising that economic growth measured in per capita GDP was overwhelming. This factor alone resulted in an increase of 799.13 MtC. During the corresponding period, through its strict family planning programmes, China experienced a very low rate of population growth in comparison to other countries at its income level, which in turn contributed to a smaller increase in China's CO_2 emissions than would otherwise have occurred.[2] Population expansion was responsible for an increase of 128.39 MtC — an increase in emissions considered to be modest, given China's large population. Also, increased use of coal in the fossil fuel mix contributed to an increase in emissions (3.93 MtC), but its role was very limited because the share of coal use in total commercial energy consumption increased only slightly during the period.

By contrast, energy conservation measures tended to push CO_2 emissions down. Since the early 1980s, the Chinese Government has been placing great emphasis on energy conservation and has formulated and implemented approximately 30 energy conservation laws concerning the administrative, legislative, economic, and technological aspects of energy conservation. After years of preparation, China's Energy Conservation Law was enacted on 1 November 1997 and came into force on 1 January 1998. In order to efficiently use energy, China has significantly reduced subsidies for energy consumption, with coal subsidy rates falling from 61% in 1984 to 37% in 1990, and to 29% in 1995, and petroleum subsidy rates falling from 55% in 1990 to 2% in 1995 (Kosmo, 1987; World Bank, 1997a). Currently, coal prices are largely decided by the market and vary significantly, depending on the destination of the coal.[3] Along with the economic reforms that, among other achievements, have spurred investment in more energy-efficient production technologies, the Chinese Government has played a crucial role both in promoting a shift of economic structure towards less energy-intensive services (see Table 5), and shift of product mix toward high value-added products. It has also encouraged imports of energy-intensive products.[4] Furthermore, efforts have been made to implement nationwide energy efficiency programmes, exemplified by the development of large coal-fired power plants. In 1987, only 11 power stations had a unit capacity of 1 gigawatt (GW) and above. The combined capacity of these

TABLE 5: The Composition of GDP in China, Japan, and the US (percentage of GDP)

	China			Japan	United States
	1980	1990	1997	1995	1995
Agriculture	30.1	27.1	18.7	2	2
Industry	48.5	41.6	49.2	38	26
Services	21.4	31.3	32.1	60	72

Sources: State Statistical Bureau (1998) and the World Bank (1997c).

---

[2] *During the period 1980-1997, the annual average growth rate of population in China was 1.33%. In contrast, the corresponding figure for low-income economies (excluding China) between 1980 and 1995 was 2.35%, and the world average was 1.66% (World Bank, 1997c).*

[3] *For example, the "mine-mouth" price of Datong mixed coal was 128 yuan per ton in June 1994. The same coal retained for 230 yuan per ton in Shanghai, 262 yuan per ton in Nanjing, 280 yuan per ton in Guangzhou, and 340 yuan per ton in Xiamen (SETC, 1996).*

[4] *About 10% of the total energy savings during the period 1981-88 were attributed to imports of energy-intensive products (Zhang, 1997a).*

TABLE 6: Growth Rates of GDP and Energy Consumption and the Income Elasticity of Energy Consumption among Different Economies, 1980-1994

	Annual growth of GDP (%)	Annual growth of energy consumption (%)	Income elasticity of energy consumption
Low-income economies[a]	2.8	4.7	1.66
• China	11.0	4.5	0.41
Upper-middle-income economies	2.5	3.9	1.56
High-income economies	2.8	1.1	0.39

[a] Excluding China.

Source: Calculated based on data from the World Bank (1996).

power stations was about 15 GW, accounting for one-seventh of the nation's total. By 1994, there were 34 power stations having a unit capacity of 1 GW and above, with a combined capacity of 43 GW, accounting for 21.4% of the nation's total (SETC, 1996). In the meantime, the share of generating units with a capacity of 100 MW and above increased from 32.5% in 1984 to 57.2% in 1994 (MOEP, 1985; SETC, 1996). Along with these large units commissioned into operation, the average generation efficiency of thermal power increased from 28.5% in 1984 to 29.7% in 1994.

Time constraints and lack of the data do not allow us to gauge the magnitude of the effect of each policy and measure on reduced energy intensity as determined by total energy consumption per unit of GDP. Clearly, however, these policies and measures have had a great impact on decoupling China's GDP growth from energy consumption, with an annual growth of 10.06% for the former, but only 5.26% for the latter (considering the period 1980-97). This achievement corresponds to an income elasticity of energy consumption of 0.52 and to an annual saving rate of 4.37%.[5] Given the fact that most developing countries at the Chinese income level have an income elasticity of energy consumption well above 1 (see Table 6), this makes China's achievement unique in the developing world.[6] As a result, a reduction of 432.32 MtC was achieved. In other words, without the above policies and measures towards energy conservation, China's CO_2 emissions in 1997 would have been 432.32 MtC (or more than 50%) higher than its actual emissions.

In addition to energy conservation, the penetration of carbon-free fuels contributed to a small reduction in CO_2 emissions (-10.48 MtC). This is mainly due to the underdevelopment of hydropower, and partly because the development of nuclear power in China is still in the start-up stage.

From the preceding analysis, it follows that China has made a significant contribution to reducing global CO_2 emissions, although none of these carbon savings have resulted from domestic climate mitigation policies. While China is making such an impressive achievement, we might ask how the OECD countries perform in this regard. They accounted for 50.3% of global CO_2 emissions in 1996 compared with 49.6% in 1990 (Jefferson, 1997), and promised at the Earth Summit in June 1992 to individually or jointly stabilise emissions of CO_2 and other GHGs at their 1990 levels by 2000. As shown in Table 7, the total CO_2 emissions in the OECD countries rose by 7.8% between 1990 and 1996. According to current trends, CO_2 emissions in the US and EU-15 (the 15 member countries of the European Union) would be 13% and 8% above the promised targets in 2000, respectively (Jefferson, 1997; Reid and

---

[5] *The income elasticity of energy consumption is defined as the change in energy consumption divided by the change in economic growth.*

[6] *As shown in Table 6, the income elasticity of energy consumption in China is quite low by international standards. In addition to energy conservation, there are two possible explanations for this. First, the growth of energy consumption is underestimated relative to the GDP growth. Second, quantitative restrictions have kept energy consumption from rising as would otherwise have occurred. Drawing on the analysis of rationing by Neary and Roberts (1980), the quantitative restrictions act like an implicit energy tax levied at rates varying with use and fuel. Generally speaking, households face a higher implicit tax than industrial users, and oil and natural gas are taxed at a higher rate than coal.*

Goldemberg, 1997). Therefore, it is fair to say that, with few exceptions, most of the OECD countries are unlikely to meet their voluntary commitments to stabilise CO_2 emissions at their 1990 levels by 2000.

Economic Effects of Future Carbon Limits for China

Although the US, the world's largest CO_2 emitter, will probably fail to honour its promise at the Earth Summit, it insists that controlling CO_2 emissions requires substantial efforts in China. The US argues that no specific commitments from China will hamper the US economy to the benefit of China, with which the US has already run a huge trade deficit. Moreover, China, whose contribution to global CO_2 emissions is already high, will soon surpass the US as the world's leading emitter of GHGs. However, the Chinese authorities have claimed that China cannot be expected to make a significant contribution to solving the carbon emission problem. They argue that ignoring the industrialised countries' responsibility for most global CO_2 emissions and simply asking for special action on China's part would seriously harm China's economic development and improvement of living standards. This contrasts sharply with the US demand. This section is devoted to explaining this difference in opinion by analysing the economic effects of possible future carbon limits for China.

To this end, a dynamic computable general equilibrium (CGE) model of the Chinese economy has been developed.[7] Using this CGE model, a baseline scenario for the Chinese economy has been developed under a set of assumptions about the exogenous variables. The baseline scenario is characterised by a rapid economic growth, with gross national product (GNP) expected to grow at an average annual rate of 7.95% for the period 1990-2010. Although the calculated rates of GNP growth are lower than those achieved in the early 1980s and 1990s, they are well in line with the government targets of GNP growth rate, which are set at 8-9% per annum for the period 1990-2000 and at 7.2% thereafter to 2010.[8] Rapid economic growth will lead to increased energy consumption and hence higher CO_2 emissions, despite substantial energy efficiency improvement. As shown in Table 8, total energy consumption is expected to rise from 987.0 million tce in 1990 to 2560.4 million tce in 2010. Consequently, the baseline CO_2 emissions are expected to grow from 586.9 million tC in 1990 to 1441.3 million tC in 2010, at an average annual rate of 4.59% for the period to 2010. Although the absolute amounts of CO_2 emissions in China are increasing in line with its rapid economic development, its carbon emissions

TABLE 7: Changes in CO_2 Emissions from Fossil Fuels Among Selected Countries and Regions[a]

	1990-1996 (%)	1995-1996 (%)
OECD[b]	+7.8	+2.6
EU-15	+0.9	+2.3
Denmark	+41.0	+20.6
Germany	–7.8	+2.1
Netherlands	+10.0	+2.6
United Kingdom	–1.0	+2.9
United States	+8.4	+3.3
Canada	+5.5	+1.6
Japan	+14.3	+1.8
Australia	+9.5	+2.2
New Zealand	+10.7	+4.0
Norway	+14.5	+7.3
CIS and C&E Europe	–31.0	–2.6
Developing countries	+32.0	+5.1
World	+6.4	+2.7

Source: Jefferson (1997).

[a] A positive sign indicates an increase; a negative sign indicates a decline.

[b] Excluding Mexico, Korea, Hungary, and Poland.

---

[7] *Zhang (1997a) and Zhang and Folmer (1998) have argued that in analysing the economic impacts of limiting CO_2 emissions, a CGE approach is generally considered an appropriate tool. For a detailed description of the CGE model for China and its application, see Zhang (1997a, 1998a, 1998b).*

[8] *Converted to the period 1990-2010, the government target of GNP growth rate ranges from 7.6% to 8.1% per annum.*

TABLE 8: Energy-Related Results for the Baseline Scenario of the Chinese Economy

	1990	1997	2010
Energy consumption (million tce)	987.0	1440.0	2560.4
Coal's share in total energy consumption (%)	76.2	73.5	67.5
Energy consumption per capita (tce)	0.86	1.16	1.80
CO_2 emissions (MtC)	586.9	847.3	1441.3
Carbon intensity of GDP (GNP) [a]	0.802	0.551	0.427
CO_2 emissions per capita (tons of carbon)	0.51	0.69	1.01

[a] Measured in tC per US$1000 at 1980 prices.

Sources: Zhang (1997a, 1998a). Author's calculations.

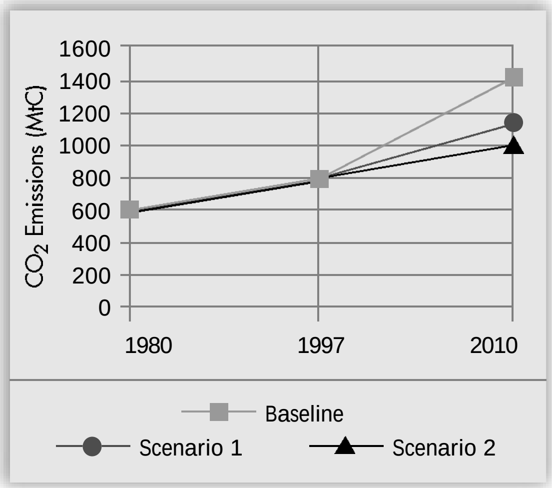
per unit of output are expected to be cut about in half during the period 1990-2010.

On a per capita basis, China's energy consumption of 0.86 tce in 1990 is expected to rise to 1.80 tce in 2010, while the corresponding CO_2 emissions of 0.51 tC in 1990 are expected to rise to 1.01 tC in 2010. Although the amounts are expected to double over twenty years, they are still well below the corresponding current world average levels, which were equal to 2.12 tce and 1.14 tC respectively in 1990 (Zhang, 1997a).

Using the CGE model, we have analysed the implications of two scenarios under which China's CO_2 emissions in 2010 will be cut by 20% and 30%, respectively, relative to the baseline (see Figure 5). Both scenarios are less restrictive in that they are compared not with the level of emissions in a single base year, but with the baseline CO_2 emissions in 2010, the latter being 2.46 times that in 1990. The carbon tax required to achieve a 20% cut in CO_2 emissions in 2010 relative to the baseline is estimated to be US$18 at 1987 prices, while the corresponding figure necessary to achieve a 30% cut in CO_2 emissions in 2010 is estimated to be US$35 at 1987 prices.[9] This means that a larger absolute cut in CO_2 emissions will require a higher carbon tax. A higher tax also implies higher fuel-specific tax rates and hence higher prices of fossil fuels.

As shown in Table 9, even under the two less restrictive carbon emission scenarios, China's GNP drops by 1.5% and 2.8%, respectively, and its welfare (measured in Hicksian equivalent variation[10])

FIGURE 5: CO_2 Emissions in China under Alternative Scenarios



Source: Author's calculations.

---

[9] *Although a carbon tax is incorporated as a means in this modelling exercise, it is not first order in considering China's response strategies for climate change. The main concern is whether China can afford or is determined to commit to an emissions cap. If there were an emissions cap for China, using a carbon tax is not impossible, given that a carbon tax is a cost-effective means of limiting carbon emissions and that China has used emission charges to control emissions of a number of pollutants, including* SO_2 *emissions in the acid rain control area.*

[10] *Equivalent variation (EV) takes the pre-policy equilibrium income and consumer prices as given and measures the maximum amount of income that a consumer would be willing to pay to avoid the price change. Because EV measures income change at pre-policy prices, this makes it more suitable for comparisons among a variety of policy changes compared with the compensating variation. At each point in time, if EV is positive, post-policy welfare is improving; if it is negative, post-policy welfare is worsening.*

drops by 1.1% and 1.8%, respectively, in 2010 relative to the baseline. This indicates that the associated GNP and welfare losses tend to rise more sharply as the degree of the emission reduction increases. Most studies estimate that the economic losses under very restrictive carbon limits (e.g., stabilisation or even 20% below 1990 levels in 2010) will not exceed 2% of GNP for the OECD countries (IPCC, 1996). Our results also support the general finding from global studies

TABLE 9: Main Macroeconomic Effects for China in 2010
Percentage deviations relative to the baseline[a]

	Scenario 1	Scenario 2
GNP	–1.521	–2.763
Welfare	–1.078	–1.753
Private consumption	–1.165	–2.972
Investment	–0.686	–1.832
Exports	–5.382	–7.447
Imports	–1.159	–2.128
Energy consumption	–19.468	–29.322
CO_2 emissions	–20.135	–30.112
Price elasticity of carbon abatement	–0.396	–0.317
Price of coal	+64.954	+123.095
Price of oil	+15.296	+29.144
Price of natural gas	+46.813	+90.564
Average price of fossil fuels	+50.888	+94.895
Price of electricity	+22.785	+43.256
Terms-of-trade	+3.636	+3.822
Nominal wage rate	–1.807	–3.043
Real exchange rate	–0.004	–0.021
User price of capital	–1.777	–4.228
Prices of exports	+3.633	+3.801
Prices of imports	–0.004	–0.021

[a] A positive sign indicates an increase; a negative sign indicates a decline.

Sources: Zhang (1997a, 1998a).

TABLE 10: Carbon Taxes by Region in 2010

	USA	Japan	EEC	Total OECD	China	World
Scenario 1	53.4	55.9	85.7	62.7	10.1	45.1
Scenario 2	120.3	103.1	158.6	132.3	18.3	92.9

Sources: Zhang (1997a, 1998a).

that China would be one of the regions hardest hit by carbon limits.[11] This, combined with the fact that the industrialised countries are responsible for most of global CO_2 emissions, explains the Chinese government stance on carbon abatement. Table 10 shows the carbon tax levels across the countries and regions considered, and demonstrates the significant differences in the carbon taxes required in order to achieve the same percentage of emission reductions relative to the baseline. It shows that the carbon taxes would be much higher in the industrialised countries than in the developing countries, because of the former's already relatively energy-efficient economies, their limited possibilities for substituting less polluting energy sources, and their high pre-carbon tax energy prices as a result of existing energy taxes. Moreover, Table 10 clearly indicates that the carbon taxes required in China in order to achieve the same percentage of emission reductions relative to the baseline are much lower than those of the industrialised countries and the world average. This provides the economic rationale for the development of carbon credit investment projects in China. Through the so-called Clean Development Mechanism (CDM) under the Kyoto Protocol, developing countries will be encouraged to combat global climate change.[12]

COMBATTING GLOBAL CLIMATE CHANGE IN THE FUTURE

Because economic development remains the priority for China, its climate policy should focus on so-called win-win strategies. However, taking on responsibilities in combatting global climate change is in China's interest, based on the following:

First, climate-sensitive sectors such as agriculture still account for a much larger proportion of GDP in China than in the developed countries (see Table 5). Thus, China is even more vulnerable to climate change than the developed countries. A broad commitment to global efforts to limit GHG emissions would reduce the potential damage from climate change in China itself, since it is not only the developed countries whose climate will change if GHG emissions are not reduced.

Second, energy is scarce in China, with per capita energy endowments far below the world average (see Table 11). Although energy consumption per unit of output in China has been cut in half since 1980, its major industries continue to use energy far more intensively than in industrialised countries (see Table 12). By making the above commitments, China will be pushed for a more efficient use of its scarce energy resources.

TABLE 11: Proven Reserves and Utilisation Rates of Fossil Fuels in China, 1997

Resources	Proved reserves	P/R ratio[a] (years)		Per capita proved reserves[b]	
	China	China	World	China	World
Coal % world total	114.5 billion tons 11.1%	82	219	95	182
Oil % world total	3.3 billion tons 2.3%	21	41	3	25
Natural gas % world total	1.16 trillion cubic meters 0.8%	52	64	967	25,517

Sources: Calculated on the basis of data from British Petroleum (1998) and the World Bank (1997c).

[a] R/P ratio stands for the lifetime of proved reserves at 1997 rates of production.

[b] Measured in tons for coal and oil and in cubic meters for natural gas and based on population in 1995.

---

[11] *There are many ways to measure the fairness of sacrifice. Here we interpret the results according to the equal sacrifice criterion that cost incurred as a fraction of GNP should be equal for each country.*

[12] *See Zhang (1998c) for a discussion of what can be expected from China after Kyoto.*

TABLE 12: A Comparison of Energy Consumption for Selected Energy-Intensive Uses

	1980 China	1994 China	Advanced level abroad
Comparable energy consumption per ton of steel (tce/t)	1.30	1.03[a]	0.6 (Italy)
Energy consumption per ton of synthetic ammonia (tce/t)			1.2
Large plants	1.45	1.34[a]	
Small plants	2.90	2.09	
Energy consumption per ton of cement clinker (kgce/t)	206.5	175.3	108.4 (Japan)
Net coal consumption of coal-fired plants (gce/kWh)	448	413	327 (ex-USSR)
Thermal efficiency of industrial boilers (%)		60-70	80-85

[a] In 1990.

Source: Zhang (1997a).

Third, driven by the threat of further degradation of the environment[12] and the harmful economic effects of energy shortages, China is already determined to push energy conservation and enhanced energy efficiency in general and more efficient coal usage in particular. Although it is making such drastic domestic efforts on its own, China badly needs assistance and economic and technical cooperation with the developed countries, because of the huge amounts of capital and technical expertise required. In this regard, the CDM, if designed appropriately, could provide an opportunity for China to get increased access to more advanced energy efficiency and pollution control technologies and additional funding.

CONCLUSIONS

In 1997, in the face of a potentially serious global climate change problem, the industrialised countries finally committed themselves in Kyoto to legally binding emissions targets and timetables for reducing their GHG emissions. Since China has made no concrete commitments, it has been criticised as a "free-rider." By examining the historical evolution of China's CO_2 emissions during the period 1980-97, however, and analysing the historical contributions of inter-fuel switching, energy conservation, economic growth, and population expansion to CO_2 emissions, we have shown that such criticism is without foundation. Indeed, China has made significant contributions to reducing global CO_2 emissions. By implementing a series of policies and measures towards energy conservation, China has cut its energy consumption per unit of output in half since 1980. In other words, without these efforts, China's CO_2 emissions in 1997 would have been 432.32 MtC higher, or more than 50% higher, than its actual emissions. Given the fact that most developing countries at China's income level have the income elasticity of energy consumption well above 1 (see Table 6), this makes China's achievement unique in the developing world, and surpasses that of the OECD countries, most of which will fail to honour their promises at the Earth Summit to stabilise CO_2 emissions at 1990 levels by 2000. Clearly, in order to correct a distorted picture that had been painted for China, more efforts must be made to effectively communicate its achievements to the outside world.

Of course, this is not to justify no further action by China. Indeed, faced with both mounting pressure from the US and the new post-Kyoto negotiating environment, and given the global

---

[13] *Existing estimates for the economic costs of China's environmental degradation vary, depending on the comprehensiveness of the estimates. For example, using the measure of willingness to pay, the World Bank (1997b) has estimated that air and water pollution cost China about 8% of its GDP, around U$54 billion annually, while Smil (1996) puts China's environmental damages between 5.5% and 9.8% of its GNP.*

characteristics of climate change and China's importance as a source of future CO_2 emissions in line with its industrialisation and urbanisation, China cannot come away without taking due responsibilities. On the other hand, economic development still remains the priority for China. For this reason, imposing a cap on its future emissions is absolutely not acceptable for China, at least until its per capita income catches up with the level of middle-developed countries. Realistic efforts and commitments that could be expected from China range from demonstrating efforts to slow its GHG emissions growth at some point between the first commitment period and 2020 to committing to a combination of a target level of energy or carbon intensity (E/GCP or C/GDP) combined with an emissions cap on a particular sector around or beyond 2020. With their focus on the win-win strategies, such efforts and commitments could be unlikely to severely jeopardise Chinese economic development. At the same time, they would give China more leverage at the post-Kyoto climate change negotiations. Though aimed at limiting GHG emissions, such strategies will also contribute to the reductions in local pollutants and thus will be beneficial to a more sustainable development of the Chinese economy as well as to the global climate.

ACKNOWLEDGEMENTS

This article has been commissioned by the United Nations Development Programme (UNDP) and the World Resources Institute (WRI). It was presented at the UNDP Workshop on Slowing Greenhouse Gas Emissions Growth while Promoting Sustainable Development, New York, 20-21 August, 1998. I would like to thank the participants in the Workshop, particularly José Goldemberg, Thomas B. Johansson, and Walter Reid, for useful discussions and comments on an earlier version of the article.

APPENDIX: DETERMINING FACTORS FOR CO_2 EMISSIONS IN CHINA

Year	POP (million)	C (MtC)	GDP[a]	TEC (Mtce)	FEC (Mtce)	GDP/POP (US$)[b]	TEC/GDP[c]	FEC/TEC	C/FEC (tC/tce)	TEC/POP (tce)	C/POP (tC)	C/GDP[d]
1980	987.05	358.60	3011.87	602.75	578.70	305	2.001	0.960	0.620	0.611	0.363	1.191
1981	1000.72	352.63	3170.25	594.47	567.66	317	1.875	0.955	0.621	0.594	0.352	1.112
1982	1016.54	367.82	3455.86	620.67	590.51	340	1.796	0.951	0.623	0.611	0.362	1.064
1983	1030.08	390.39	3832.34	660.40	625.66	372	1.723	0.947	0.624	0.641	0.379	1.019
1984	1043.57	421.41	4413.94	709.04	674.23	423	1.606	0.951	0.625	0.679	0.404	0.955
1985	1058.51	456.58	5008.53	766.82	729.63	473	1.531	0.952	0.626	0.724	0.431	0.912
1986	1075.07	482.01	5452.52	808.50	770.42	507	1.483	0.953	0.626	0.752	0.448	0.884
1987	1093.00	517.32	6083.45	866.32	826.12	557	1.424	0.954	0.626	0.793	0.473	0.850
1988	1110.26	554.98	6768.91	929.97	886.08	610	1.374	0.953	0.626	0.838	0.500	0.820
1989	1127.04	577.37	7044.13	969.34	921.94	625	1.376	0.951	0.626	0.860	0.512	0.820
1990	1143.33	586.87	7314.16	987.03	936.40	640	1.349	0.949	0.627	0.863	0.513	0.802
1991	1158.23	618.90	7986.64	1037.83	988.01	690	1.299	0.952	0.626	0.896	0.534	0.775
1992	1171.71	650.12	9123.88	1091.70	1038.21	779	1.197	0.951	0.626	0.932	0.555	0.713
1993	1185.17	687.61	10354.59	1159.93	1099.61	874	1.120	0.948	0.625	0.979	0.580	0.664
1994	1198.50	724.65	11665.79	1227.37	1157.41	973	1.052	0.943	0.626	1.024	0.605	0.621
1995	1211.21	771.24	12891.31	1311.76	1231.74	1064	1.018	0.939	0.626	1.083	0.637	0.598
1996	1223.89	820.71	14127.21	1389.48	1313.06	1154	0.984	0.945	0.625	1.135	0.671	0.581
1997	1236.26	847.25	15370.91	1440.00	1357.92	1243	0.937	0.943	0.624	1.165	0.685	0.551

Sources: Based on data from the State Statistical Bureau (1992, 1998); Author's calculations.

Pop = Population
C = Carbon emissions
TEC = Total energy consumption
FEC = Fossil fuel consumption

[a] Measured in US$100 million at 1980 prices and at the average exchange rate US$1 = 1.5 Chinese yuan.
[b] At 1980 prices.
[c] Measured in tce per US$1000 at 1980 prices.
[d] Measured in tC per thousand US$ at 1980 prices.

REFERENCES

British Petroleum, 1998: BP Statistical Review of World Energy, *1998.* London.

Ehrlich, P. and A. Ehrlich, 1990: The Population Explosion. Touchstone, New York.

Energy Research Institute, 1991: CO_2 emissions from fossil fuel combustion and reduction countermeasures in China. Bulletin of Energy Policy Research, No. 2 (State Planning Commission, Beijing), 4-7.

IPCC, 1996: Climate Change 1995: Economic and Social Dimensions of Climate Change. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, UK.

Jefferson, M., 1997: Potential climate change: carbon dioxide emissions, 1990-96. World Energy Council Journal, 76-82.

Kosmo, M., 1987: Money to Burn? The High Costs of Energy Subsidies. World Resources Institute, Washington, DC.

MOEP, 1985: Electric Power Industry in China, 1984-85. Ministry of Electric Power (MOEP), Beijing.

Neary, J.P. and K.W.S. Roberts, 1980: The theory of household behaviour under rationing. European Economic Review, **13**, 25-42.

Reid, W. and J. Goldemberg, 1997: Are developing countries already doing as much as industrialized countries to slow climate change? Climate Notes, World Resources Institute, Washington, DC.

SETC, 1996: China Energy Annual Review. State Economic and Trade Commission (SETC), Beijing.

Smil, V., 1996: Environmental Problems in China: Estimates of Economic Costs, East-West Center, Honolulu, Hawaii, US.

State Statistical Bureau, 1992: Energy Statistical Yearbook of China, 1991. State Statistical Publishing House, Beijing.

State Statistical Bureau, 1998: A Statistical Survey of China, 1998. State Statistical Publishing House, Beijing.

UNCTAD, 1998: Greenhouse Gas Emissions Trading: Defining the Principles, Modalities, Rules and Guidelines for Verification, Reporting and Accountability. United Nations Conference on Trade and Development (UNCTAD), Geneva.

UNFCCC, 1997: Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). FCCC/CP/1997/L.7/Add.1, Bonn, Germany.

World Bank, 1994: China: Issues and Options in Greenhouse Gas Emissions Control. Washington, DC.

World Bank, 1996: World Development Report, 1996. Oxford University Press, New York.

World Bank, 1997a: Expanding the Measure of Wealth: Indicators of Environmentally Sustainable Development. Washington, DC.

World Bank, 1997b: Clear Water, Blue Skies: China's Environment in the New Century. Washington, DC.

World Bank, 1997c: World Development Report, 1997. Oxford University Press, New York.

Zhang, Z.X., 1997a: The Economics of Energy Policy in China: Implications for Global Climate Change. New Horizons in Environmental Economics Series, Edward Elgar, England.

Zhang, Z.X., 1997b: Operationalization and priority of joint implementation projects. Intereconomics (Review of International Trade and Development), **32**(6), 280-292.

Zhang, Z.X., 1998a: Macroeconomic effects of CO_2 emission limits: a computable general equilibrium analysis for China. Journal of Policy Modeling, **20**(2), 213-250.

Zhang, Z.X., 1998b: Macro-economic and sectoral effects of carbon taxes: a general equilibrium assessment for China. Economic Systems Research, **10**(2), 135-159.

Zhang, Z.X., 1998c: What can be expected from China after Kyoto? University of Groningen, Groningen, The Netherlands.

Zhang, Z.X. and H. Folmer, 1998: Economic modelling approaches to cost estimates for the control of carbon dioxide emissions. Energy Economics, **20**(1), 101-120.

CHAPTER 4

India's achievements in energy efficiency and reducing CO_2 emissions

Rajendra K. Pachauri
Director
Tata Energy Research
Institute (TERI)
New Delhi, India

Sudhir Sharma
Research Associate
TERI, New Delhi, India

SUMMARY: Energy plays a central role in India's development efforts and its mandate to alleviate poverty. For this reason, promoting energy efficiency, conservation, and renewable energy technologies are key aspects of India's development objectives. Although overall energy use is expected to continue to rise along with India's population and GDP, government initiatives and policies, particularly since 1990, are affecting India's CO_2 emission intensity (emission from energy use per unit GDP), which has levelled off and shows signs of declining. Energy efficiency has shown improvement as well, in large part because of a change in pricing structures and a reduction of energy subsidies. India's promotion of renewable energy, especially for rural areas, represents another significant action to limit greenhouse gases (GHGs). Though India, like other developing countries, has not taken on specific commitments to mitigate CO_2 emissions, it is making progress in this direction.

INTRODUCTION

The United States has made its ratification of the Kyoto Protocol contingent on "meaningful participation" by key developing countries, especially India, China, and Brazil. The US has argued that although the developed countries are now the major contributors to greenhouse gas (GHG) emissions, increasing emissions from developing countries would make their contribution larger in the not-too-distant future. Therefore, without the participation of the developing countries, global progress towards GHG emissions limitations would be severely restricted.

The need for developing countries to improve living standards and reduce poverty is well understood. The average per capita GNP for developing countries was US$982 in 1992 in comparison to US$16,065 for industrial countries (UNDP, 1995). A large percentage of developing country populations live in poverty. A sizeable fraction of the population does not have access to basic amenities such as health services, drinking water, and sanitation. Therefore, the immediate priority of these countries is to address the basic needs of their populations. Energy is the key driving force in the process of development. Though the total energy use, one of the major sources of emissions, is increasing in developing countries, their per capita energy consumption remains far below that of the developed world. Commercial energy consumption for the year 1992 was 527 kg of oil equivalent (kgoe) per capita in developing countries compared to 4834 kgoe per capita in developed countries (UNDP, 1995). Commercial energy consumption in India was 235 kgoe per capita compared to 7662 kgoe per capita in the USA (UNDP, 1995).

A number of developing countries have undertaken structural reforms with the aim of globalising their economies and making them competitive in the international market. These include fuel price reform, energy sector deregulation, the promotion of energy efficiency, and renewable energy resources to meet national development objectives. Although the developing countries have not undertaken specific commitments to mitigate CO_2 emissions, these measures have had significant ancillary benefits with regard to climate change.

This chapter analyses energy use in India from this perspective and argues that the need for increasing energy use in developing countries is a necessity rather than a luxury. The first section analyses trends in emissions and their underlying causes. The second section discusses overall trends in the energy intensity of the Indian economy and the underlying causes of the changes. The third section considers the driving forces behind energy demand in the Indian economy and the imperative for meeting it in order to alleviate poverty. The last section reviews some of the measures undertaken by the Government of India in meeting energy demands in an efficient manner, with an emphasis on renewable alternatives that have positive implications for climate change.

We have restricted the analysis to emissions from energy use, as they constitute more than 90 per cent of CO_2 emissions. Also, the focus on energy sector does not imply absence of efforts in other sectors. Emissions from land use change and forestry sector were estimated to be negligible in 1990 (ALGAS, 1998). In fact, since 1980 there has been a significant increase in forest cover, which can be estimated as an additional sink for sequestration of CO_2. If the national Forestry Action Plan adopted by the Government is implemented in the coming years, the extent of sequestration would increase further. The efforts in increasing productivity of agriculture, both of milk and grains, has also resulted in potential emissions reduction. Two main sources of CH_4 emissions in the agricultural sector are enteric fermentation and emissions from paddy fields. For example, productivity of paddy increased from 1336 kg per hectare in 1980 to 1839 kg in 1996. This increase has decreased emissions per unit of paddy output.

EMISSION INTENSITY OF THE INDIAN ECONOMY

The total estimated GHG emissions of the Indian economy in 1990 were 268 Tg of carbon equivalent (TgC). Emissions from energy use — 154 TgC — accounted for 57% of the total GHG emissions and 96% of total CO_2 emissions (ALGAS, 1998). This compares with total GHG emissions in the US from energy use alone of 1355 TgC (WRI, 1994). In India, energy-related emissions more than doubled from 1980[1] (82 TgC) to 1994 (195 TgC), though the rate of increase has declined since 1990. The annual rate of growth for CO_2 emissions was 6.8%[2] during the 1980s, and the growth rate fell to 4.9% for the period 1990-1994. Figure 1 shows the changes in CO_2 emission intensity[3] in India since 1980. As mentioned earlier, a large proportion of emissions come from use of fossil fuels to meet energy needs. Given the country's development priorities and the need for poverty alleviation, total emissions from India are expected to increase in the future. But this does

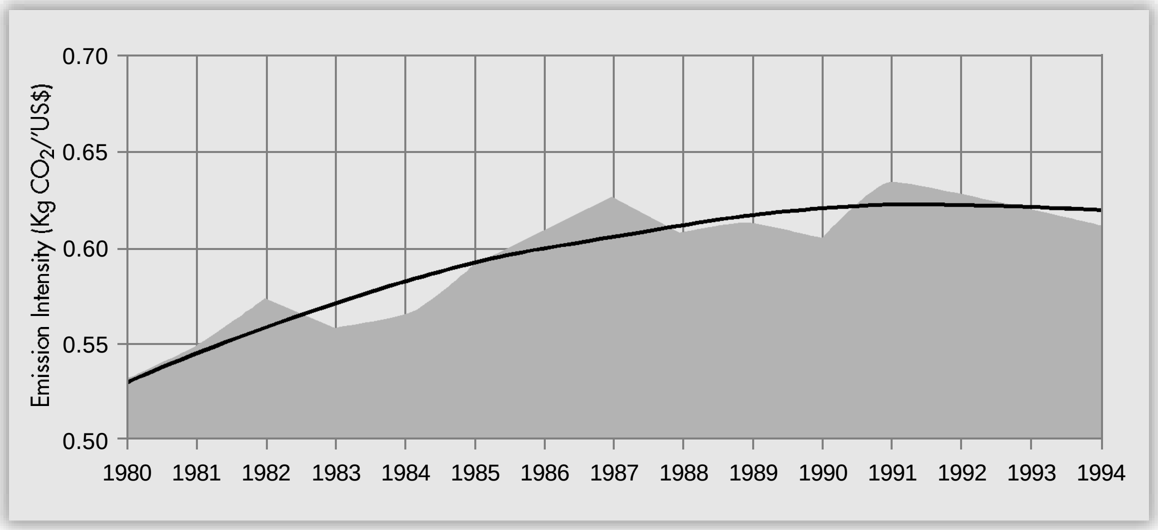
---

[1] *1980 refers to financial year April 1980 to March 1981. The growth rates and figures mentioned in the text refer to financial year.*

[2] *Annual growth rates reported are compound growth rates unless otherwise mentioned.*

[3] *Emission intensity is CO_2 emission from energy use per unit of GDP. Emissions for the economy are calculated on the basis of primary energy use in the economy. IPCC default values have been used to estimate emissions from the quantity of different primary fuels consumed. This also includes emission from primary fuels that are used for non-energy purposes. To that extent, these emissions are an overestimate.*

FIGURE 1: CO_2 Emission Intensity of GDP

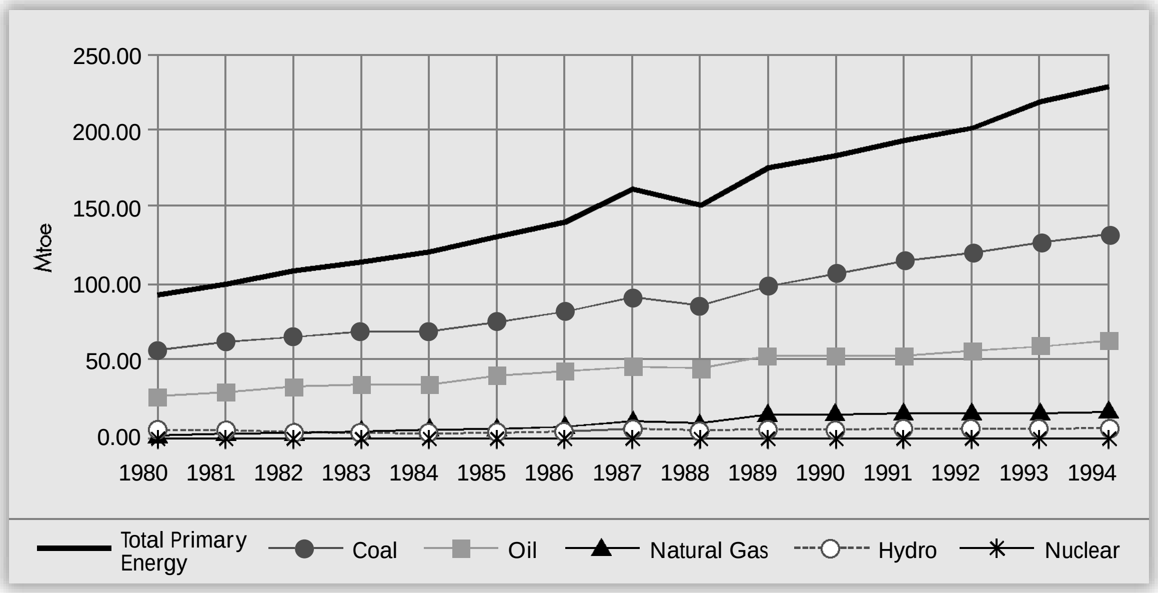


Source: TERI, 1997.

not necessarily mean that the emission intensity of GDP will also increase. This becomes clear from the trend of the emission intensity curve in Figure 1, and by extrapolating the recent downward slope into the future.

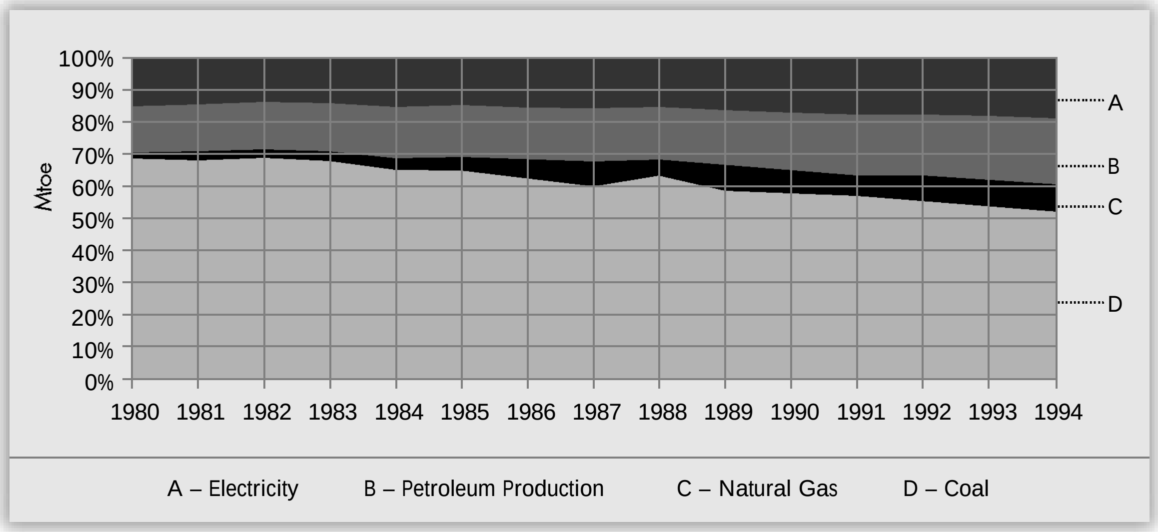
Energy emissions are a function of the total amount of fuel used in the economy, the fuel composition, and the efficiency of conversion devices. Total primary (commercial) energy use in the Indian economy grew at a rate of 6.7% for the period 1980-1994. The rate of growth in primary commercial energy was 7.1% for the 1980s, which slowed down to 5.6% in the 1990s. As reliable time series data on non-commercial energy use are not available, it is difficult to analyse total energy use for this period. However, an estimated 40% of total energy demand in the

FIGURE 2: Primary Energy Use in the Economy



Source: TERI, 1997.

FIGURE 3: Fuel Composition of Final Energy Consumption



Source: TERI, 1997.

Indian economy is met through non-commercial energy sources such as biomass, cowdung, and wood (TERI, 1997). The share of non-commercial energy was 66% in 1970 according to the Indian Planning Commission. In India, as in other developing economies, an increase in demand for commercial energy is a function of the increasing size of the economy, changes in the efficiency of energy use, and substitution of non-commercial energy with commercial energy.

Figure 2 shows the growth in total primary energy use in the economy as well as its sources. Because of large reserves, coal has been India's major energy source and is likely to remain so in the future. However, coal's contribution to total energy has remained constant since 1980. India has very limited reserves of crude oil; hence, most crude oil and petroleum products are imported. Use of oil increased in the early 1980s, but the relative flattening of total oil consumption since then suggests slower growth in liquid hydrocarbons relative to total energy consumed. The share of natural gas, though small, has increased rapidly because of policies promoting use of gas through increased recoverable reserves and because of a decrease in flaring of associated natural gas.

Figure 3 shows the changing composition of fuels in final energy consumption since 1980. The share of electricity and natural gas has increased, and the share of coal has decreased in this period, with a greater percentage of it going towards power generation. The use of coal in the transport sector has been totally phased out — it is now used primarily for industry and electricity generation. All sectors show a trend away from the use of coal to cleaner fuels for heating. This should be seen coupled with the fact that an increasing amount of electrical drive energy is now met through conversion of coal into electricity. Of the country's total generating capacity, about 70% comes from thermal power. There have been significant efforts to increase the efficiency of generation and minimise losses in the electricity sector. Electric utilities have also taken steps to reduce demand through the promotion of more efficient equipment. These efforts will reduce the emissions intensity of production. A switch to cleaner fuels for heating is also helping to decrease overall emissions intensity. Until 1990, however, natural gas did not substitute for "dirtier" fuels, but mainly replaced non-energy use. With increasing availability of natural gas, industry's use of it has increased. A fairly clean fuel source, natural gas emits 50% and 30% less CO_2 per unit of heat content than coal and oil, respectively.

Thus, we see that there have been certain changes in the economy to reduce CO_2 emission's intensity (CO_2 emissions/GDP). One of the most important reasons for this decrease is the economy's increased energy efficiency. The next section analyses the changes in India's energy intensity since 1980.

ENERGY INTENSITY OF THE INDIAN ECONOMY

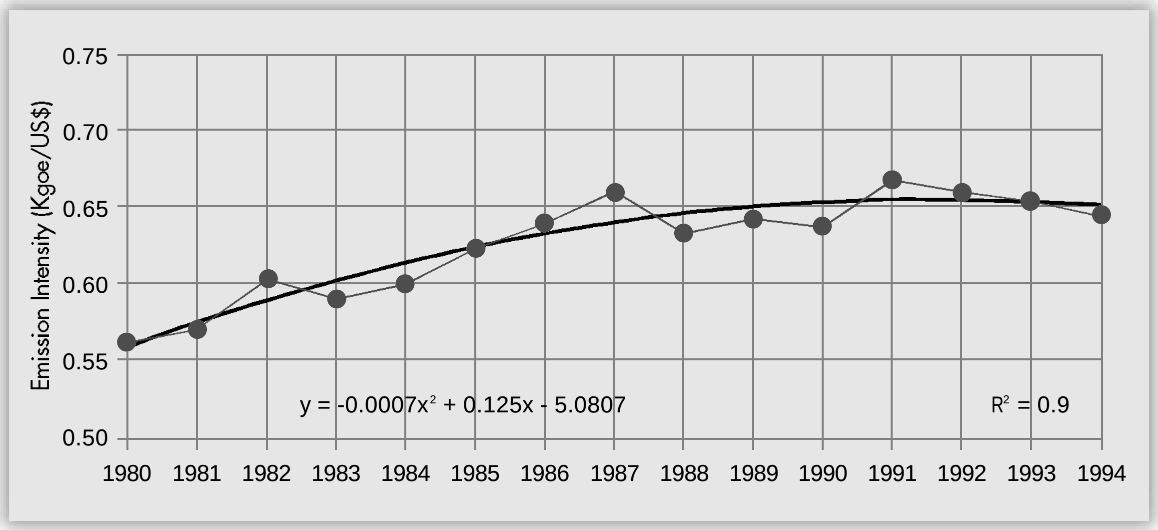
As mentioned earlier, the rate of growth of primary commercial energy use in the Indian economy was 7.1% for the decade of the 1980s, slowing down to 5.6% in the 1990s. The economy overall has shown higher growth since the mid-eighties than in earlier decades. Policy reforms since 1991 have strengthened growth trends. The economy grew at 5.5% during 1980-1985, 5.8% between 1985 and 1990, and 6.8% in 1992-1997. The declining growth rate of energy use with an increasing rate of growth in the GDP indicates improvement in gross energy use efficiency. This is also reflected in the fact that the primary energy[4] elasticity of the economy fell from 1.26 in the 1980s to 1.06 in the 1990s.

Figure 4 shows changes in energy intensity[5] of E/GDP since 1980, with the thick dark line indicating the overall trend. The increase in primary commercial energy use per unit GDP slowed down during the 1985-90 period, and a distinct flattening of the curve is visible after 1990. Energy use is a function of the sectoral composition of the economy, energy use characteristics of individual sectors, and the composition of fuel use in the economy. Changes in sectoral composition of the Indian economy are shown in Figure 5.

As is typical of a developing economy, the sectoral composition shows a distinct shift towards an increase in the industrial and the service sectors. The service sector has been separated into transport and other services. The energy intensity of the industrial sector[6] is much higher than that in the agriculture and service sectors. The share of the transport sector, too, has increased since 1980, and shows the highest energy intensity in terms of use per unit of output. Without considering the energy intensity of the individual sectors, the changing composition — with a higher share for transport and industry — would have resulted in increased energy intensity.

Table 1 demonstrates that the increase in energy use has resulted from sectoral composition changes in the economy. In Column 1 we calculate the total energy use in the economy, assuming that energy intensities for individual sectors are constant at 1980 levels. In Column 2 we calculate total energy use in the economy, assuming that

FIGURE 4: Energy Intensity of GDP since 1980



Source: TERI, 1997.

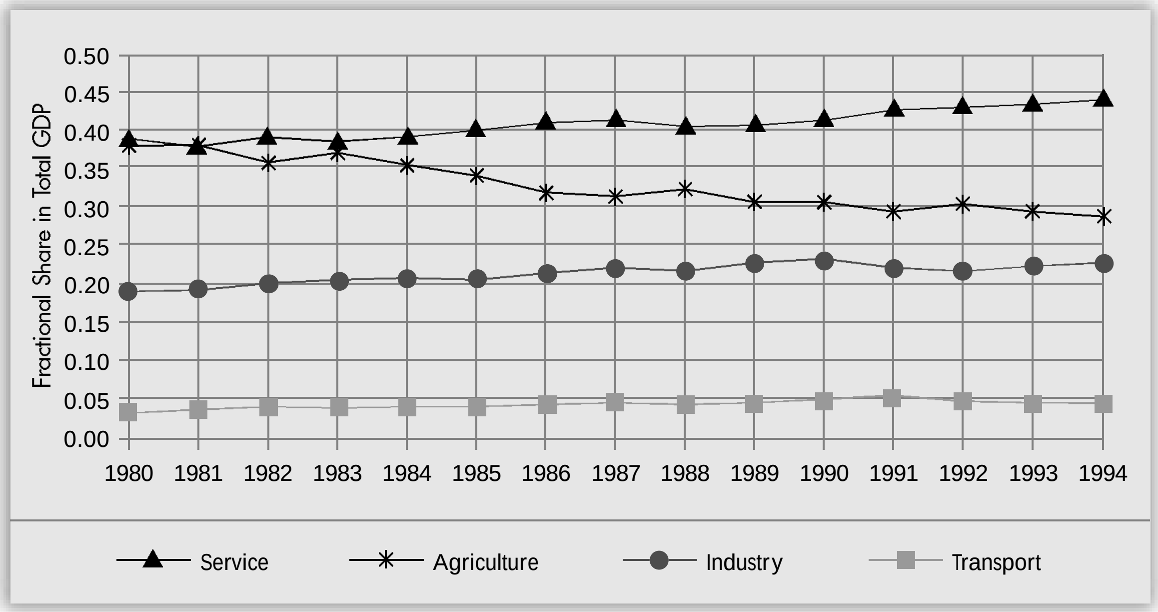
---

[4] *Unless otherwise mentioned, energy here refers to commercial energy.*

[5] *Energy intensity calculation excludes non-energy use of fuels.*

[6] *Industrial sector includes mining and quarrying and manufacturing. Agriculture sector constitutes agriculture, forestry and logging, and fisheries.*

FIGURE 5: Changing the Sectoral Composition of the Indian Economy



Source: TERI, 1997.

the sectoral composition of the economy remains the same as that in 1980. Column 1 indicates that had there been no change in the energy intensity of individual sectors, the total energy use would have been the same as the actual use in 1994.

As explained earlier, however, the composition of the economy has shifted towards sectors that have a higher energy requirement per unit of output, so it is not surprising that total energy requirements would increase. The comparison of columns 1 and 3 indicates that the shift towards energy-intensive sectors of the economy has been balanced by a decrease in energy intensity of some or all sectors. In other words, if the structure of the economy had not changed, we would probably have seen a decrease in total energy used.

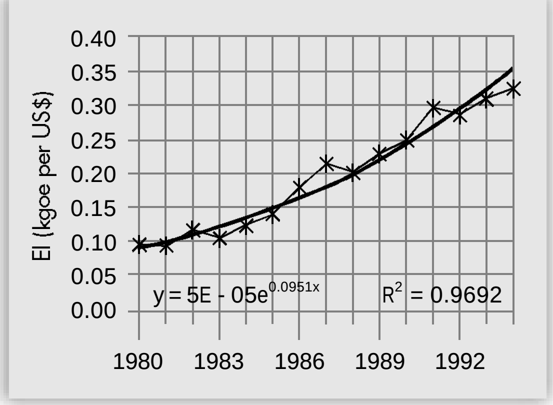
The energy intensity trends for the major sectors — *viz.*, industry, transport, services, and agriculture — are shown in Figures 6a-d.

Energy intensity of the agricultural sector grew at a rate of 10% annually. Still, this represents very low energy use, even compared to that in several other developing countries. The energy intensity of the service sector increased by 2.5% annually. In contrast, the energy intensity of the industry and transport sectors declined. Therefore, total

TABLE 1: Comparison of Actual Energy Use with Energy Use with Sector Composition and Energy Intensity Held at 1980 Levels

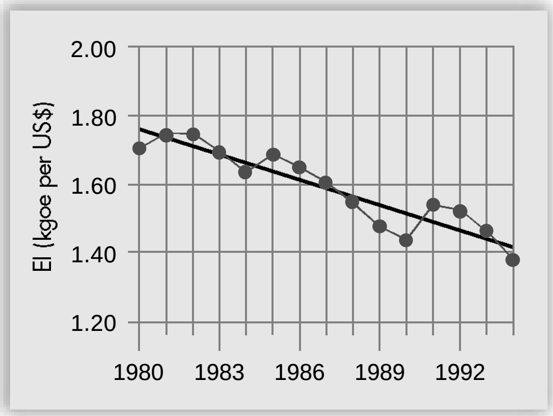
	Total energy requirement (million toe)		
	Assuming 1980 emission intensity	Assuming 1980 sectoral composition	Actual
1980	87.3	87.33	87.33
1981	93.5	92.93	93.77
1982	98.7	99.14	102.39
1983	106.9	105.03	108.53
1984	113.6	108.51	114.40
1985	119.8	115.80	123.49
1986	128.0	121.75	132.06
1987	136.9	138.22	151.90
1988	148.9	130.54	142.00
1989	163.8	148.30	163.85
1990	173.4	155.39	171.48
1991	173.1	166.40	181.08
1992	180.6	173.94	188.00
1993	192.8	183.11	197.85
1994	209.8	192.98	209.50

FIGURE 6a:
Energy Intensity of Agriculture Sector



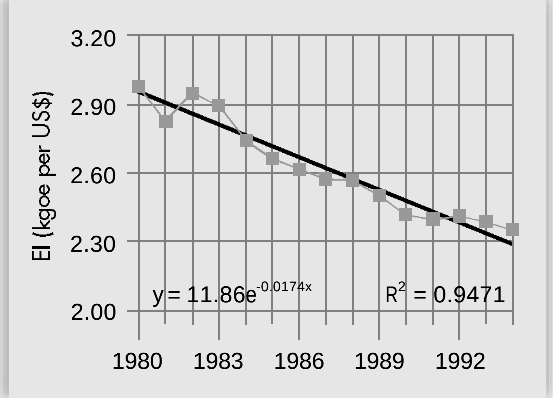
Source: TERI, 1997.

FIGURE 6b:
Energy Intensity of Industry



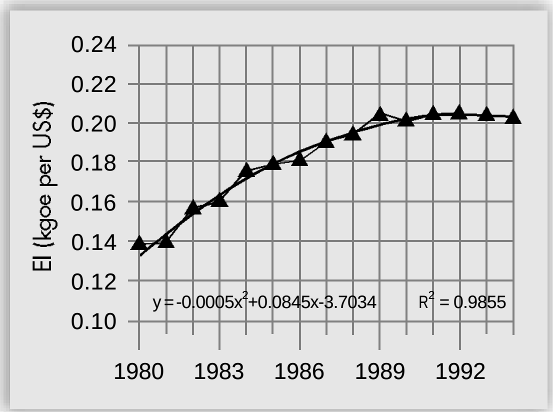
Source: TERI, 1997.

FIGURE 6c:
Energy Intensity of Transport Sector



Source: TERI, 1997.

FIGURE 6d:
Energy Intensity of Service Sector



Source: TERI, 1997.

energy use was affected by three factors: a structural shift away from agriculture, increasing energy intensity in the agriculture sector, and declining energy intensity in the industry and transport sectors.

Table 2 breaks down the changes in total energy intensity by sector over three 5-year intervals, showing each sector's contribution to total GDP and change in its energy intensity. Calculations for the period 1980-1994 show that agriculture represented a smaller portion of the GDP, and thus helped bring about a decline in the total energy intensity. However, the increase in agricultural energy intensity was higher, and so it made a net positive contribution in the overall energy intensity. Despite its declining share of the GDP, agriculture still constitutes 30% of the total economy — a sizeable portion. The increased share of the service sector, as well as its increased energy intensity, resulted in an increase in total energy intensity. Thus, the agricultural and service sectors represented a positive contribution to total energy intensity.

The increase in energy intensity throughout the period can be attributed to an increase in agricultural energy intensity and the service sector's larger role in the economy, with its inherently high energy intensity. To quantify the effects of these two factors, we calculated the use of energy in the economy, keeping the agriculture energy intensity and service energy intensity constant at 1980 levels. As Table 3 shows, had agricultural energy intensity not increased, India's energy use in 1994 would

TABLE 2: Contributions of Individual Sectors to the Change in Energy Intensity

	Agriculture	Industry	Transport	Services	Total change
Change between 1980 and 1994					
GDP change	–3.81	6.44	1.97	1.86	
EI change	10.85	–7.93	–3.05	4.16	
Total	7.03	–1.49	–1.09	6.02	10.48
Change between 1980 and 1989					
GDP change	–1.93	6.83	1.93	0.90	
EI change	6.23	–5.59	–2.28	3.93	
Total	4.30	1.23	–0.35	4.82	10.01
Change between 1989 and 1994					
GDP change	–1.07	0.06	0.16	0.94	
EI change	3.80	–2.78	–0.90	0.25	
Total	2.73	–2.72	–0.74	1.19	0.47

Note: GDP change represents the change in contribution (in fraction) of the sector and the effect of this on change in energy use.

have been 10% below the actual level. Similarly, the increase in energy intensity of the service sector accounted for 5.7% of the total energy use increase between 1980 and 1994.

The decline in energy intensity in the industrial and transport sectors had a negative net contribution to the GDP. Contributions from the agriculture and service sectors offset the increasing influence of energy intensity reduction in the industry and transport sectors. To analyse the cause of the slower increase in energy intensity after 1990, we have broken the period into two time spans, 1980-1989 and 1989-1994. An analysis of the period 1980-1989 shows that the net contribution of the three sectors, excluding transport, was positive. Industry's increasing share of the GDP countered the decline in energy intensity in the sector. During the nineties, the declining energy intensity in the industry and transport sectors was much stronger. This countered the increasing energy intensity in the agriculture sector. Also, after 1990 energy intensity in the service sector stabilised, as demonstrated in Figure 6d.

Table 3 also shows the contribution of the industry and transport sectors to the overall decrease in energy intensity. Had there been no improvements in energy efficiency in the industrial sector, the total energy use in 1994 would have been 11.6% higher than it actually was. Likewise, without efficiency improvements in the transport sector, 4.4% more energy would have been needed to support the economy. Thus, improvements in the transport and industry sectors helped reduce energy requirements by 16%.

ENERGY DEMAND: THE DRIVING FORCE IN INDIVIDUAL SECTORS

The higher energy intensity in the agriculture sector is largely due to the spread of the green revolution, with its increasing mechanisation of farm operations and increased energy use for irrigation. The net area for crops has remained constant at 140 million hectares. In the future, therefore, increases in production will have to come from an intensification of agriculture, as there are no more viable farmlands. Since independence, India has come a long way in achieving self-reliance in grain production. Nevertheless, the challenge of feeding a population growing by 18 million people each year is not over. Increasing population and purchasing power will increase the demand for food in the future. The only possibility of meeting this demand is by increased productivity.

TABLE 3: Contribution to Change in Energy Use from Different Factors

	Actual Energy Use	Energy use (EI for agriculture at 1980 level)	Energy use (EI for services at 1980 level)	Energy use (EI for industry at 1980 level)	Energy use (EI for transport at 1980 level)	Energy use (EI for industry & transport at 1980 level)
1980	87.33	87.33	87.33	87.33	87.33	87.33
1981	93.77	93.78	93.61	92.67	94.71	93.61
1982	102.39	101.25	100.80	101.26	102.60	101.46
1983	108.53	107.83	106.37	109.21	109.11	109.79
1984	114.40	112.47	110.85	117.31	116.18	119.09
1985	123.49	120.51	119.38	124.36	126.05	126.92
1986	132.06	126.76	127.45	134.73	135.27	137.94
1987	151.90	142.80	143.05	152.52	154.24	154.85
1988	142.00	135.34	137.14	154.57	147.90	160.46
1989	163.85	153.51	155.44	177.26	169.15	182.56
1990	171.48	159.16	162.29	188.29	178.11	194.92
1991	181.08	165.66	171.10	191.25	188.30	198.47
1992	188.00	171.74	177.80	199.56	195.48	207.03
1993	197.85	179.10	187.10	214.28	205.93	222.36
1994	209.50	188.52	197.47	233.70	218.64	242.83
% change		10.02	5.74	11.55	4.36	15.91

Indian agriculture is still largely dependent on rainfall. In 1992, only a third of the net cropped area was under irrigation. Thus, increasing productivity calls for increasing the irrigation base of the country, as well as increased use of fertilizers and pesticides. Increased mechanisation is seen as a complement to these inputs. In this context, India's need to intensify energy use in the agricultural sector becomes clear.

As mentioned earlier, reliable data on energy use are available only for commercial energy. The increased energy intensity in agriculture reflects the shift to equipment using commercial energy to substitute for bullock power and manpower. Traditionally, human labour and livestock have been the main energy sources for Indian agriculture, and this situation continues despite the substantial mechanisation that has taken place. Farm operations like digging, transplanting, weeding, harvesting, and paddy threshing are still performed manually. India has about 200 million agriculture workers providing 43,000 terajoules (TJ) of manpower and 80 million draught animals providing 81,000 TJ of animal energy. It is estimated that more than 55% of land is cultivated by draught animal power (TERI, 1997). Mechanical power, however, has begun to replace this energy source and will probably continue to do so in the foreseeable future.

The increase in commercial energy use does not reflect the actual energy intensity of agricultural output. The share of human energy use in the total farm power use decreased from 35% in 1950 to 8% in 1995. The share of energy supplied by draught animals decreased from 55% in 1950 to 12% in 1995. Limited land availability and increasing demand from a growing population mean that a limited number of draught animals can be supported. This implies that mechanical power will increasingly have to supply the energy demand formerly met through draught animals.

Another factor in interpreting increasing energy use in agriculture is conversion losses. Energy intensities are calculated based on primary energy use in the agricultural sector, which reflects the conversion losses as a proportion of the total electricity used by a sector. Agriculture consumed 30% of total electricity produced in 1994. Therefore, the sector's energy intensity also reflects efficiency of conversion in the economy. Improving efficiency in power generation and supply would also decrease agriculture's contribution to energy intensity.

Agricultural electricity is highly subsidised, leading to wasteful use. The output-to-input ratios for irrigation pumping have gone down considerably. The energy use has increased greatly, but over a very small area with disproportionately low incremental increases in yields. Therefore, water conservation — although still maintaining an increase in yields — and a shift to energy-efficient tilling and harvesting operations offer promise for greater efficiency.

To calculate energy intensity for the service sector, total primary energy in the commercial and residential sectors was added, segregating the income to individual sector is not possible. The increasing energy intensity thus reflects increasing replacement of non-commercial energy with commercial energy in the residential and service sectors. The rising per capita incomes associated with urbanisation increase demands for both end-use energy and energy products and services (room heating, electrical appliances etc.). The energy intensity changes in the commercial sector do not reflect the overall increases in efficiency. There has been considerable substitution towards kerosene and liquefied petroleum gas (LPG) in the urban domestic as well as commercial sectors. LPG's penetration in urban areas increased from 10% in 1979 to 27% in 1991. Similarly, the number of households using electricity rose from 63% in 1979 to 76% in 1991. Increasing electrification of rural areas has also increased the total commercial energy use in the residential sector. In 1994, 18% of total electricity generated was used in the residential sector — up from 11% in 1980. According to the latest statistics, fewer than 30% of rural households have electricity. Increasing electrification of rural areas, increasing incomes, and increasing urbanisation suggest that a substantial substitution of commercial for non-commercial energy is likely to occur for quite some time.

The third major sector driving energy demand is transport. The output of transport sector grew annually an average of 6.6% between 1980 and 1994 (TERI, 1997). The growth has been led by an expansion of road transport, which grew at an growth rate of 7.15%, whereas the railway sector grew at only 3.57%, due largely to more freight being handled on the roads. Surface movement of both goods and passengers has steadily increased. Much of the increase in passenger travel is correlated to the increase in private vehicles in urban areas. The number of two-wheelers (motorcycles and scooters) increased by 18.4% per annum during the 1980s, and the total number of vehicles increased by 14.8% during the same period. About 80% of the total is personal transport vehicles, with two-wheelers making up 68% of the total. The lack of adequate public transportation in urban areas is one factor in the increased use of private vehicles. Also, at higher income levels, people tend to use private vehicles more. The study group on "Alternative Systems of Urban Transport" projected a total demand of 443 billion passenger kilometres in 83 cities with populations of more than a quarter million. Nearly 80% of the demand will be met through road transport (Ministry of Urban Development, 1987). Urban rapid transport systems are being planned in major cities.

India's extensive network of railways covers 62,915 km and handles 11,000 trains daily. Total running track length in the country was 108,513 km in 1995. But a large part of this was developed before independence. The growth in track length in the last couple of decades has been negligible. Most of the capital improvements have been directed towards electrification and gauge conversion. This has affected the growth of both passenger and freight traffic in the railways. A large portion of rail freight is in bulk goods, such as coal, cement, and food grains. Much of the non-bulk traffic has moved to the road sector.

Indian Railways have introduced a number of measures to increase the share of goods moved by rail. Passenger rail traffic in India has been heavily subsidised by freight traffic. In the 1998 fiscal year budget, an attempt was made to reduce this cross-subsidisation by increasing passenger tariffs. Moving goods by rail is five to six times more energy-efficient than moving them by trucks. Any increase in the share of freight movement through railways will reduce the energy-intensity of the transport sector.

TABLE 4: Indicators of Improvements in Energy-Intensive Industries in India

	Conservation measures: electricity coefficient measure (kWh/‘000 tonne)		Specific energy consumption in fertilizer industry (Gcal/tonne)			Specific energy consumption in ISP (kWh/tonne)
	Aluminium	Paper industry	Gas	Naphtha	Fuel oil	
1980						678
1981						307
1982						621
1983	20,023	1718				727
1984	19,834					718
1985		1691				698
1986						664
1987			10.22	12.78	13.95	685
1988	17,942		10.04	12.23	14.32	664
1989			9.62	12.35	14.36	
1990			9.63	11.92	15.08	
1991	17,548	1650	9.55	11.74	13.53	
1992			9.48	11.73	13.9	650 (P)
1996	15,910 (P)	1597				

ISP: Integrated Steel Plant; P: Provisional

Two factors are responsible for the changes in energy intensity in the industrial sector. First, there has been a structural shift towards non-energy intensive industries (such as electrical and non-electrical machinery, automobile manufacturing, pulp and paper, and food processing) from energy intensive sectors (such as iron and steel, aluminium, and textiles). Industry has also shifted towards use of new technologies (which are inevitably more energy-efficient) and towards energy conservation. The economic reforms undertaken in 1991 made it easier to expand industrial production. This was aimed at increasing the competitiveness of the economy. Measures were instituted to allow the flow of foreign investment as direct investment. At the same time, a number of measures were undertaken to increase exports, and a restructuring of the tariff regime was undertaken with the aim of globalising the economy. These measures to foster global competitiveness have led to the adoption of more efficient technologies and, because energy costs are a major component of total costs, to better energy management by industry. The liberalisation process and the increase in incentives to cut costs have led to greater energy efficiency, although such efforts actually predate liberalisation.

Technological advances, such as the use of catalysers, have resulted in lower energy intensity in some industries. For example, consumption of naphtha per tonne of ammonia fell from 0.9 to 1 tonne in 1970 to 0.8-0.85 tonne in 1990. In the same period, the consumption of ammonia per tonne of urea dropped from 0.6 to 0.58 tonne. Increasing the share of fuel and power costs in the textile industry prompted about 15% of the mills to take up major energy conservation measures. A number of efforts are being undertaken to restructure the steel industry as a way of reducing energy intensity (TERI, 1997). These include moving out of the open-hearth process and increasing capacity of the continuous casting process. Table 4 quantifies the effect of some of these measures.

EFFORTS IN IMPROVING USE INTENSITY IN INDIAN ENERGY SECTOR

Energy is a major and essential input in the early stages of economic development. The importance of the energy sector in India is highlighted by the fact that 30% of the government's budget has generally been earmarked for energy. One of the constraints to healthy future growth is the capacity of the economy's infrastructure, which is now identified as inadequate. Energy is the most important element of this infrastructure. Large investments in the energy sector are required to support its desired rates of economic growth.

The strategy of increasing the efficiency of resource use and productivity of the economy is an important complement to efficient development of infrastructure. Although environmental and sustainability issues are critical in defining economic policy and energy-related initiatives, the problem of widespread poverty requires that primacy be given to rapid economic growth. Nevertheless, India has taken major steps to improve overall use of energy in the economy.

The share of electricity use in the economy has grown steadily over the past decade and a half. India's average transmission and distribution losses are 21% (TERI, 1997), and auxiliary power consumption is estimated at 8% (Ministry of Power, 1996). As a result, losses in conversion account for a sizeable fraction of total primary energy use. To increase the efficiency in electricity generation and increase capacity utilisation, in 1984 the Government of India launched a centrally sponsored programme for renovation and modernisation of thermal power stations. A similar plan was launched for hydro-electric power stations in 1987. In phase I of the scheme, 34 power stations, with a total capacity of 13,570.5 MW, were targeted to generate an additional 7000 million kWh per annum. Against this, the actual additional generation from such measures was 52.7 billion kWh for the period 1988-1993. Phase II of the programme will cover 46 thermal power stations with total capacity of 21,664 MW. The hydropower initiative will cover 55 hydro plants with installed capacity of 9658 MW. To make the electricity sector commercially viable, the government has established the Central Electricity Regulatory Commission (CERC). State Electricity Regulatory Commissions (SERCs) are expected to regulate electricity prices and handle other matters covered by the Electricity Regulatory Commissions Act of 1998.

India has been at the forefront of renewable energy use. Renewable energy sources are generally an economically viable option for decentralised energy supply in remote areas. The importance of renewables is reflected in the fact that India has had a full-fledged and independent Ministry of Non-conventional Energy Sources (MNES) since 1990. It was initially set up as a separate department in the government in 1982. In 1992 the government moved away from state-sponsored programmes to commercialisation of renewable energies technologies (RETs). A separate financial institution — the Indian Renewable Energy Development Agency (IREDA) — was set up in March 1987 to promote, develop and finance RETs. During 1995, IREDA offered loan assistance of Rs 6022.2 million for 265 projects. The cumulative loan commitment of IREDA through 31 March 1996 was Rs11,074.8 million. All these efforts resulted in generation capacity of approximately 1400 MW of power through renewables by March 1997. Table 5 quantifies the increase in various renewables.

The Government of India provides an explicit subsidy to a range of renewable energy technologies. In addition to these direct subsidies, it offers other indirect benefits in the form of accelerated depreciation schedules and other tax breaks. These

TABLE 5: Expansion of RET Capacity in India

Device	Achievements		
	1993	1994	1997
Biogas plants (in millions)	1.8	2.2	2.5
Improved chullah (in millions)	14.5	19.6	23
Solar cookers (in millions)	0.29		0.43
Wind farms (MW)	53.9	350.51	900
Small hydro (MW)	93.4	119.56	141
Biomass power (MW)			83
PVs (MW)			28

Chullah: traditional cookstove

Source: TERI, 1997.

efforts are supplemented by institutional measures to promote private investment in this sector. For instance, the government is considering establishment of a national certification and testing center for wind turbines. A National Bio-energy Board (NBB) has been set up to direct policy and guide energy recovery from urban and industrial wastes.

Whereas several of the current initiatives apply to urban locations and to grid-based supply, NBB's efforts primarily address the energy requirements of rural communities through decentralised generation. Because they replace centralised power generation and have zero emissions, they reduce the carbon emissions that would otherwise have been produced. India's average transmission and distribution losses are 21% (TERI, 1997), and auxiliary power consumption is estimated at 8% (Ministry of Power, 1996). This implies that 1.3 units of electricity must be generated to supply 1 unit of electricity for consumption. Assuming a 30% availability of renewable power generation capacity, the total amount of electricity generated in a year from installed capacity is 3 billion kWh. Estimated CO_2 emission per kilowatt-hour of electricity generated from coal-based power stations is 1.3 kg (ALGAS, 1998). Thus, the generation of electricity through renewables means that 1.44 million tonnes of C emissions per annum are avoided.

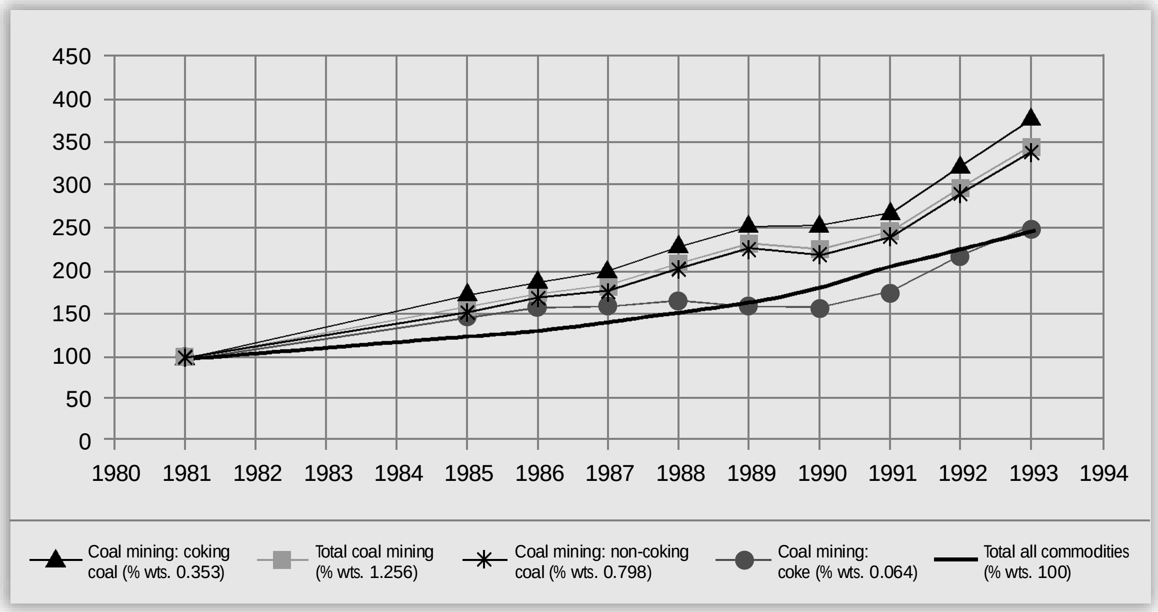
A major factor in inefficient use of energy has been its sub-optimal pricing. Almost all the commercial fuels in India in the past were subjected to pricing mechanisms, other than purely economic or commercial reasons. Government pricing had an adverse effect on organisations responsible for energy supply, leading to inefficient patterns of energy use throughout the country. Since 1990, policy has shifted towards market-driven pricing. In 1996, the Government of India de-regulated prices of certain grades of non-coking coal and all grades of coking coal. A policy decision also stipulates that the pricing regime for other grades of non-coking coal too would be de-regulated beginning 1 January 2000.

The government pricing regime in the hydrocarbons sector also has started undergoing major changes. Parallel marketing has been approved for kerosene, liquefied petroleum gas (LPG), and lubricants. Also, private parties are now allowed to import these products and sell them through their own marketing networks at market-driven prices. Imports of naphtha and jet fuels have been decanalised for their own use by the importers. A number of other measures are under consideration that could significantly change the pricing regime or eliminate it altogether.

A high degree of subsidisation still exists in electricity pricing, although a number of states are also in the process of changing the existing structure to make this sector market-driven as well. Subsidised prices have diminished the ability of the state electricity boards to generate resources for expansion and improvements both internally and from private sector sources. They also promote inefficient use of energy. A number of states have undertaken tariff reforms to make state electricity boards more viable. The State of Orissa was the first to initiate reforms in the state's power sector. The Orissa State Electricity Board, a state monopoly combining all the functions relating to generation, transmission, and distribution of electricity, has been replaced by separate corporate entities: the Grid Corporation of Orissa, Orissa Hydro Power Corporation, and Orissa Power Generation Corporation. An independent regulatory authority has been established to determine prices in the state for all categories of electricity consumers. The Haryana State Restructuring Bill (1997) has been adopted by the state assembly and has received Presidential assent.

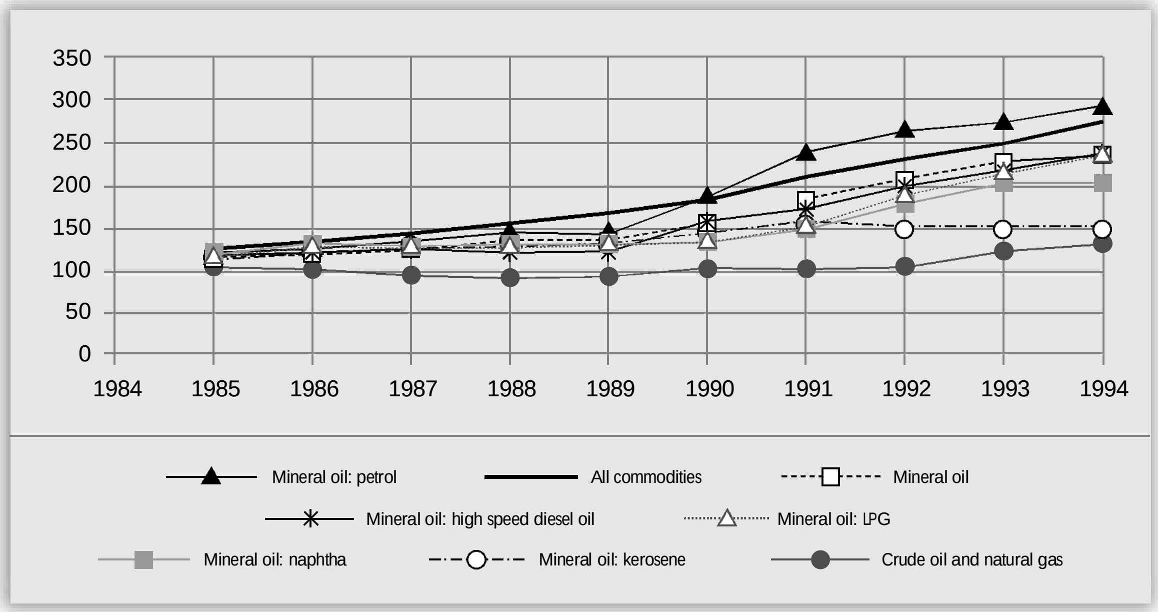
Such efforts would build further on the recent changes in energy prices. Figures 7a-c show changes in price indices of coal, electricity, and petroleum products for the period 1984-1994. Thick dark lines in the graphs represent the price indices for all commodities. Except for coke, the prices of all grades of coal have increased in real terms since 1990. The increase has been steeper since 1990 — a trend to which the price of coke conforms as well. The price of petroleum products remained almost unchanged throughout the 1980s. Except for crude oil and naphtha, the prices of products have increased sharply since 1990. The prices for liquefied petroleum gas, petrol, and diesel

FIGURE 7a: Wholesale Price Index of Coal



Source: TERI, 1997.

FIGURE 7b: Wholesale Price Index of Crude and Natural Gas

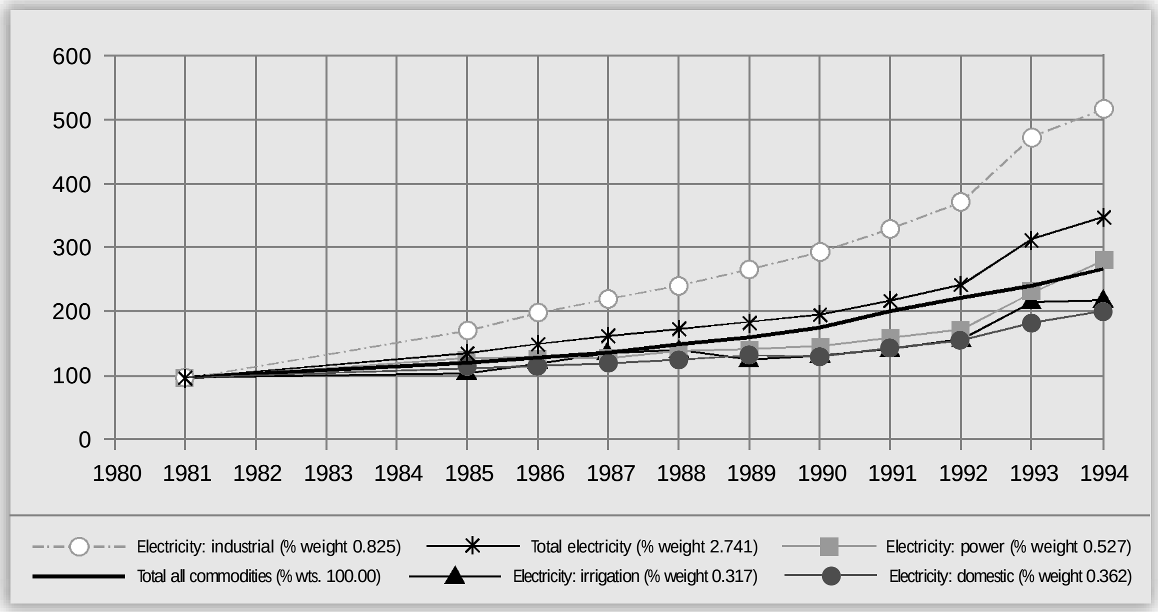


Source: TERI, 1997.

increased in real terms after 1990.

The price of electricity for domestic and agriculture sectors has decreased in real terms, as shown in Figure 7c. However, with pricing reforms expected in most states, consumers will also probably have to pay higher prices in the near future. The industrial sector has been bearing the major share of the total generation cost, which is reflected in the sharp increase in electricity price for industries. In the aggregate, the real prices of energy have grown at 2.3% since 1981 and at 3.7% since 1990.

FIGURE 7c: Wholesale Price Index of Electricity



Source: TERI, 1997.

CONCLUSION

Although development objectives and social priorities dictated the pricing of energy products in the past, the current trend reverses this pattern and is moving in the direction of market-driven pricing. The fiscal reforms and liberalisation measures adopted by the Government of India in 1991 and consistently pursued by successive governments clearly demonstrate India's commitment to reducing the energy intensity and the CO_2 emissions per unit of output in the Indian economy. The annual budget of the Government of India approved by Parliament provides a substantial increase (100%) in the outlay for IREDA as well as a significant increase in the allocation for the Ministry of Environment & Forests. In addition, several other incentives have been provided for conversion of waste to energy. Similar initiatives are also being taken by state governments and municipalities.

At an assembly of the Global Environment Facility (GEF) in New Delhi in early April 1998, India's Prime Minister, Atal Bihari Vajpayee, strongly reiterated the country's commitment to the promotion of solar energy and other forms of renewable energy technologies as well as to more efficient use of other energy resources. The fact that he made these pronouncements after less than a month in office underscores that India's partnership with the rest of the world in limiting CO_2 emissions is not simply an act of global responsibility but is also undertaken to meet national goals. However, given their clearly defined "common but differentiated responsibility" (Article 4, UNFCCC, 1992), the developed countries must assume ambitious commitments and discharge them with conviction. The US emphasis on the "meaningful participation" of key developing countries not only attempts to bypass this responsibility but also ignores the enormous changes already taking place in the right direction in India — changes that require no imposition of unfair commitments on this country.

REFERENCES

ALGAS draft report, 1998: Asia Least Cost Greenhouse Gas Abatement Strategy. Report submitted to Ministry of Environment and Forest, Government of India.

Ministry of Power, 1996: India's Electricity Sector — Widening Scope for Private Participation. Ministry of Power, Government of India, New Delhi.

Ministry of Urban Development, 1987: Report of the Study Group on Alternative Systems of Urban Transport. Ministry of Urban Development, Government of India, New Delhi.

TERI, 1997: TERI Energy Data Directory and Yearbook. Tata Energy Research Institute, New Delhi, India.

UNDP, 1995: Human Development Report, 1995. United Nations Development Programme, New York.

WRI, 1994: World Resources, 1994-95. World Resources Institute, New York.

……

CHAPTER 5

Energy initiatives in Africa for cleaner development

Ogunlade R. Davidson
Dean of Engineering
University of Sierra Leone
Visiting Professor, UNEP
Centre, RISØ Laboratories
Roskilde, Denmark

SUMMARY: Although Africa is a vast and tremendously diverse continent, some general comments can be made about its energy trends. Despite considerable, though unevenly distributed, energy resources among its countries, energy use across the continent is the lowest anywhere. Per capita use of commercial fuels averages just one-third of that for South America or Asia. However, African countries are fully supportive of the principles of the Climate Change Convention. They are willing to take actions to combat climate change, so long as such actions also satisfy their development aspirations. Renewable energy technologies, which currently represent only 2% of the continent's energy use, seem particularly promising in this regard, and many countries are pursuing solar and biomass energy systems. Efforts are also underway in several African countries to shift to natural gas and to more efficient forms of power generation. The pace of clean development in Africa could be accelerated by increased access to financial and technological resources.

INTRODUCTION

Africa is the second largest continent in the world, comprising 53 countries of diverse cultures and differing physical, natural, and human resources. These features, coupled with its colonial past and arbitrary historical border divisions, give rise to more commonalities across countries than within them. Africa's population, the fastest growing in the world, is currently estimated at 778.5 million, which gives it one of the lowest average population densities on earth. However, its countries are highly divergent: population density varies by a factor of over 100 among countries, and differences in energy resources are even more marked. Most of the continent's share of global crude oil and natural gas reserves — 7.6% and 6.7%, respectively — are in only three countries: Algeria, Angola, and Nigeria. Almost 90% of its coal reserves are in South Africa.

As a result of both internal and external factors, African countries have experienced sluggish economic growth since 1980, with an annual growth in GDP of only 1.3% between 1990 and 1995 (World Bank, 1997). However, owing to improvements in agricultural production and fiscal management, significant progress has been achieved in many countries, while there have been armed conflicts in a few others. Since 1996, the continent as a whole has recorded annual GDP growth of about 4%, with some countries growing by more than 6% (ADB, 1997). Significantly, economic growth now surpasses population growth.

However, consumption of commercial fuels in Africa is very low by world standards. In 1995, only 209.4 Mtoe — 0.29 toe per capita — of commercial fuels were consumed. This represents only about one-third of what is used by an Asian or South American, on average. Low industrial activity and use of commercial fuels account for Africa's small share of global emissions of CO_2, which is by far the most important greenhouse gas (GHG). Nevertheless, current trends indicate that this share may increase as African countries achieve their socio-economic goals.

Despite their low contribution to both cumulative and current global GHG emissions, African countries have been active participants in the search for global and regional solutions to the problem of climate change. At the United Nations Conference on Environment and Development (UNCED) in Brazil in 1992, 38 of the 53 African countries signed the United Nations Framework Convention on Climate Change (UNFCCC), and 12 ratified it by March 1994 before it came into force. Further, African countries were fully involved in the different forums that led to the adoption of the Kyoto Protocol in December 1997. Also, two African countries, Senegal and Zimbabwe, have submitted their initial national communications to the UNFCCC, and more than 30 African countries are currently undergoing studies that will enable them to do so. These efforts demonstrate that African countries are politically committed to solving the global climate change problem.

In pursuit of their socio-economic goals, African countries have been adopting cleaner development paths relative to past global practises. They have been actively engaged in the climate challenge by avoiding GHG emission-intensive paths. However, their efforts have yet to be recognised, in part because they have not been analysed and documented. This chapter documents some of these efforts and actions.

UNFCCC AND THE KYOTO PROTOCOL: PERSPECTIVES OF AFRICA

The ultimate objective of the UNFCCC is to stabilise atmospheric GHG concentrations at a level that will prevent dangerous anthropogenic interference with the climate system. African countries are fully supportive of the principles of the Climate Change Convention, which include cost-effectiveness, common but differentiated responsibilities, intra- and intergenerational equity, and the satisfaction of non–Annex I countries' needs in terms of food production and sustainable development. These principles are very important to African countries, because of their urgent development and social needs. Hence, African countries are willing to take actions to combat climate change, but such actions must also satisfy their development aspirations.

Most of the African countries attended the Third Conference of Parties (COP-3), where the Kyoto Protocol was adopted. The Protocol requires Annex I parties to reduce their GHG emissions below their 1990 emissions by an average of 5.2% in the period 2008–2012. The negotiations at COP-3 made it clear that Annex I Parties should take the lead in slowing down the climate change threat. Because of the current interactions and inter-linkages within the global socio-economic systems, however, satisfying the ultimate objectives of the UNFCCC will require collective efforts by all nations.

Some of the unresolved critical issues of the Kyoto Protocol will have profound effects on future technology and financial flows to all developing countries. Because of the inertia in the climate system, the agreed reduction target of GHG emissions by 5.2% below 1990 levels by Annex I Parties by 2010 is considered inadequate to reduce the build-up of GHGs in the atmosphere (Bolin, 1998). Thus, the Protocol should be considered an initial step towards greater reductions after 2012 — even if the stipulated targets of the Annex I Parties are met. Added reductions will have to include some commitments by non–Annex I Parties, whose emissions are projected to surpass those of developed countries by 2020 (Reid and Goldemberg, 1997). These trends will increase pressure for commitments by developing countries in future negotiations of the Protocol, even though Annex I Parties are responsible for the major share of historical GHG emissions. However, targets and timetables for non–Annex I Parties will require new co-operative efforts to ensure their right to economic development, while keeping to the principle of differentiation as agreed in the Protocol.

Article 12 of the Protocol defines a Clean Development Mechanism (CDM) whose purpose is to assist non–Annex I Parties to achieve sustainable development while contributing to the ultimate objectives of the Climate Change Convention. The details of how this mechanism will work are not yet resolved. Discussions surrounding the potential of GHG removal by sinks will be of considerable interest to developing countries. Many other issues, such as the relationship between CDM and other international financial arrangements (including the Global Environment Facility, official development assistance, and foreign direct investment), remain unclear. This is important because experience shows that there could be adverse effects. The administrative complexities that are normally associated with international mechanisms may surpass the national capacities of many African countries. Technical challenges, such as evaluation of baselines, emissions, and financial additionality, may create additional problems. Resolving these issues will require assistance from developed countries. In addition, many African countries may need to strengthen certain capacities — including the overall business environment and private sector and the training and education level of the work force — before they can benefit from the possible opportunities CDM may offer.

TABLE 1: Carbon Emissions from Fossil Fuel Burning in Selected Annex I and Non–Annex I Parties to the Convention

Country		Total Emissions, 1996 (million tons)	Emissions per Capita (tons)	Growth in Emissions 1990–96 (%)
Annex I Parties	USA	1433	5.35	8.8
	Russia	414	2.81	–32.7
	Japan	308	2.44	12.5
	Germany	241	2.94	–7.6
	UK	151	2.56	–2.0
	Canada	115	3.82	5.3
Non-Annex I Parties	China	846	0.68	29.3
	India	250	0.26	37.6
	South Korea	104	2.27	82.5
	South Africa	95	2.24	16.8
	Mexico	94	0.98	11.2
	Iran	76	1.13	35.9

Source: Flavin & Dunn, 1997.

The countries in the Organisation for Economic Co-operation and Development (OECD), which form the major part of Annex I, agreed to voluntarily cut their CO_2 emissions to 1990 levels by the year 2000. Progress to date makes it unlikely that these countries will meet this voluntary target. Carbon dioxide emissions from non–Annex I Parties increased by about 25% between 1990 and 1995, although the overall growth could have been substantially higher if not for the actions pursued by some of these countries. Table 1 gives the overall carbon emissions between 1990 and 1996 for the main emitting Annex I and non–Annex I Parties.

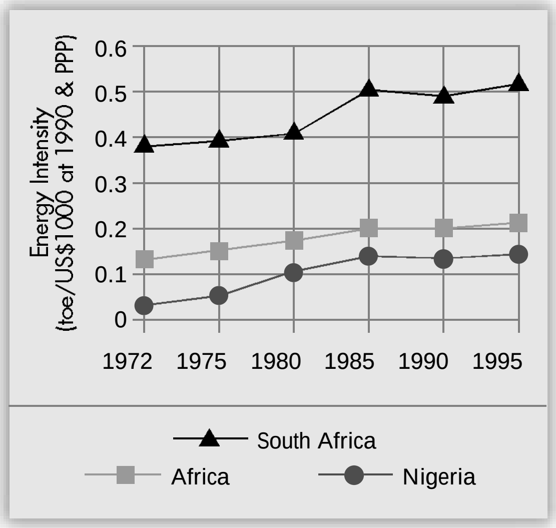
ENERGY TRENDS IN AFRICA

Africa is endowed with unexploited and diverse non-renewable and renewable energy resources, but consumes the lowest-quality energy in the world. Africa's share of global crude oil, natural gas, and coal reserves in 1995 amounted to 7.6%, 6.7%, and 6%, respectively (B.P., 1996). Further, more reserves of oil and gas have been found in the central region of the continent. Only about 5% of the continent's hydropower potential, which exceeds 200 GW, has been exploited. With most of the continent in the tropics, its biomass and solar energy potential is virtually inexhaustible. However, these vast resources have not been fully tapped to improve the quality of life of its citizens because of an uneven distribution of resources, limited co-operation among countries, and infrastructural limitations. Though significant trading takes place among African countries in crude oil, petroleum products, and electricity, most of the energy produced is exported. In 1995, 77.6% of the oil produced in the continent was exported, mostly to Europe and North America. At the current rates of production, oil and gas reserves will last for more than 30 years and coal for more than 200 years.

The consumption of commercial fuels has been rising steadily in Africa for 25 years, from just over 66.5 Mtoe in 1971 to 209.4 Mtoe in 1995. Coal use almost doubled, and consumption of crude oil more than tripled in this period. The persistent drought in southern Africa contributed to the increase in coal use. The use of natural gas became significant in the late 1970s and increased fivefold by 1995. The growth in per capita use of modern fuels doubled within the period, from just over 0.16 toe to just over 0.32 toe.

Consumption of electricity has been growing faster than that of liquid fuels in the same period, increasing by almost a factor of 5, from 80 to 380 TWh. Hydropower, which dominated power production in the 1980s, lost its share to oil fired plants, owing to climatic factors and capital constraints. Significant amounts of electricity are produced from coal-fired plants — mainly in South Africa, which accounts for over 40% of total electricity produced in the continent. The industrial and transport sectors dominate the use of commercial fuels, with 43% and 24.2%, respectively.

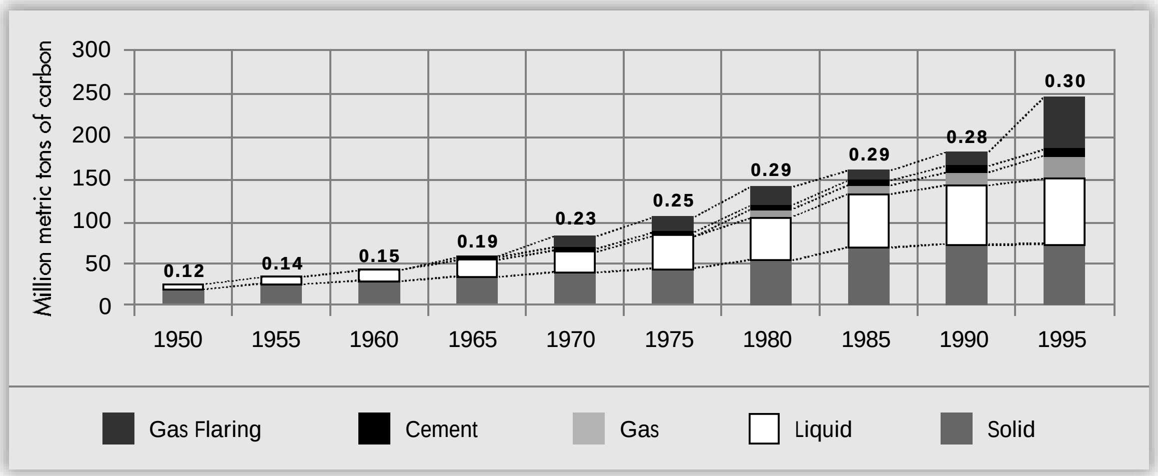
FIGURE 1: Energy Intensity for Africa and Selected Countries



Source: Derived from IEA/OECD, 1997.

The low level of energy use on the continent and equally low industrial activity in comparison to other developing regions account for Africa's very low energy intensity — an average of 0.18 toe/US$1000 (PPP at 1990). Intensity trends, as indicated in Figure 1, show that it increased from 0.13 in 1972 and then stagnated around 0.2 from 1985 onwards, with similar trends for two major countries in the region,

FIGURE 2: Carbon Dioxide Emissions from Africa, 1950–1995



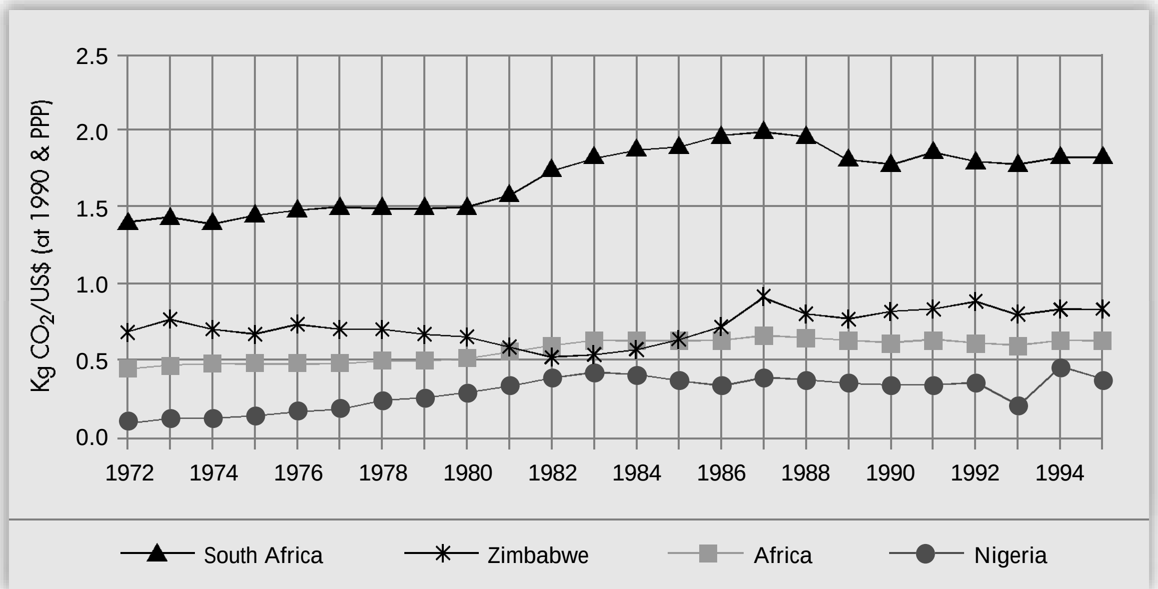
Numbers above bars indicate per capita emissions in metric tons.

Source: IEA/OECD, 1997.

Nigeria and South Africa. This increase was due to faster growth in energy demand over the economic growth rate, a result of strong demand for energy services from non-productive sectors. However, like most other regions of the world, Africa is using energy more efficiently now than the past. The higher energy intensity in South Africa than in other countries is due to its dominance in energy usage in the continent.

In 1995, CO_2 emissions from the fossil fuel burning and cement manufacture sector in African countries were almost 7.5 million metric tons, accounting for 3.3% of the global total (WRI/ UNEP/UNDP/World Bank, 1998). Between 1950 and 1995, CO_2 emissions grew tenfold, from 25 to almost 250 million metric tons, as shown in Figure 2. During that period, per capita emissions rose from 0.12 to 0.3 metric ton of carbon. These emissions were primarily from the use of solid fuels — mostly coal, which accounted for about 37% of carbon emissions in 1995 compared to 73% in 1950. Since 1950, use of oil-based fuels has increased. Liquid fuels, mostly oil, accounted for 36% of total emissions in 1995, up from 28% in 1950 (WRI/UNEP/UNDP/World Bank, 1998).

FIGURE 3: Carbon Intensity for Africa and Selected African Countries



Source: IEA / OECD, 1997.

Emissions from gas and cement production are very small, though increasing use of gas has started to be reflected in the share of emissions from gas on the continent. In global terms — with the exception of South Africa, which relies heavily on coal for power production and now accounts for about 1.4% of global GHG emissions — future emissions from the continent will continue to be low for the near future.

In general, developing countries have been shifting steadily to the use of natural gas, which emits about 40% less carbon than coal, especially for new power plants, owing mainly to the economic and technical advantages of this resource. In addition, governments in countries with natural gas, such as Nigeria, are using different incentive measures to promote its use. Between 1985 and 1995, the use of natural gas increased by 146% in Asia, 70% in Latin America, and 71% in Africa (B.P., 1996). The increase in Africa could have been much higher were it not for infrastructural limitations. However, use of natural gas has been growing in Africa at an average rate of 5% annually — but much more quickly in Algeria and Nigeria, which have significant reserves of natural gas. Because these gas plants are replacing oil-fired plants, they are helping to limit GHG emissions. Current trends show that growth of gas-fired plants will increase at a significantly faster rate in the future.

Biomass, used mainly for cooking, is the major source of energy in the household sector. Biomass is estimated to account for 71.5% of total primary energy used in 1995. Its poor conversion rate — only 15–20% is actually transformed into useful energy — contributes greatly to this high usage figure. The use of modern renewable energy sources, mainly solar energy, is recent and not yet significant, accounting for about 2% of the total.

Trends in carbon intensity in Africa are similar to its energy intensity trends. Carbon intensity showed a slight increase in the early 1980s, stabilizing in the mid 1980s (see Figure 3). The increase was due to growth in energy demand — especially that of high-carbon-intensive fuels such as coal in the south, as demonstrated in the case of South Africa and Zimbabwe (where increase started a few years later). The stabilisation that follows is due to a slight improvement in energy efficiency and a shift to low-carbon-intensive fuels such as natural gas (in Nigeria, for example).

The potential for growth in the energy sector of Africa is huge, but investment and technical obstacles have limited its realisation. For some time, African countries have embarked on many development projects to address basic human needs and improve their overall net productivity, while also addressing other concerns, such as climate change. Industrial activities on the continent are comparatively low, comprising less than 2% of world industrial output. Hence, Africa's efforts in the arena of climate change fall mostly in the sectors of energy, forestry, agriculture, and waste management.

AFRICA'S RENEWABLE ENERGY INITIATIVES

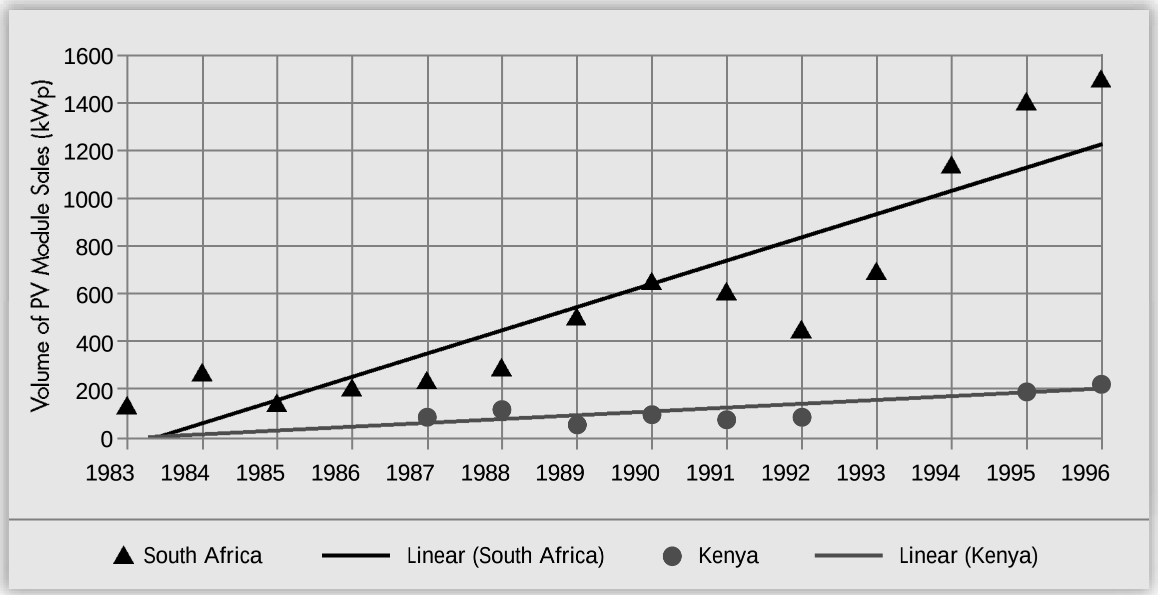
Africa's major energy sector initiatives have involved low GHG-emitting energy sources, including renewable energy technologies (RETs). The widespread use of RETs on the continent was triggered by the search for alternatives to crude oil after the oil price crisis of the 1970s. In a few cases, other energy security concerns forced governments to intervene in the energy sector — for example, in Zimbabwe's development of ethanol. Improvements in the power and building sectors driven by developmental concerns also reduced the share of GHG emissions in the energy sector. The drive to improve living conditions in rural and remote areas has led to the

TABLE 2: Estimates of Solar Photovoltaic Solar Home Systems in Selected African Countries

Country	Estimated Number of Systems	Estimated Installed Capacity (kW_P)	Year
South Africa	40,000-60,000	1850	1996
Kenya	20,000-60,000	250	1996
Zimbabwe	12,800	596	1997
Senegal	1600	60	1997
Zambia	2100	88	1993
Botswana	Fewer than 2000	NA	1992
Uganda	538	152.5	1993
Mali	2000	70	1997
Burundi	1800	58	1993
Rwanda	941	29	1991

Sources: AFREPREN, 1997; Various issues of *INFORSE Newsletter,* 1996–98; Annual Report of GEF Zimbabwean Project, 1997.

FIGURE 4: Estimated Size of PV Markets in Kenya and South Africa



Source: Data derived from Acker &Kammen, 1996, and *INFORCE*, February 1997.

penetration of RETs in some of these areas. The use of agricultural wastes for power production in agro-based industries, especially in the sugar industries that are widespread on the continent, have a beneficial impact on GHG emissions.

Solar photovoltaics (PVs), mini-hydro, and improved biomass cooking stoves are the most successful RETs to have been introduced in African countries after the oil shocks of the 1970s. Solar PVs are widely used for satisfying lighting and other electrical needs in certain market niches, such as rural homes and certain institutions. Solar home units are very popular in many countries, and the rate of dissemination is quite high. Table 2 gives an estimate of installations in selected African countries. They totalled over 120,000 units of varying sizes (from 25 to 150 Wp), with an estimated installed capacity of 3.15 MWp. Thus, they saved the equivalent of 3.15 MW of oil-based or coal-based power.

The prospects for substantial growth of these systems in the continent are good. As shown in Figure 4, installations of solar PV home units in Kenya increased from 85 to 220 kWp between 1987 and 1996. It is estimated that about half of the sales are donor-driven, and government actions, such as reduction of tariffs and taxes, have stimulated local development and assembly. Currently, batteries, lighting systems, and charge regulators are produced locally. The increase was even more dramatic in South Africa, where sales grew from 130 to 1500 kWp between 1983 and 1996. The sudden increase in sales after 1994 was due primarily to direct government purchases and rural electrification programmes from the national utility. In Zimbabwe, 9800 new 45-W units were added between 1993 and 1997 as part of a UNDP/GEF project. This project has stimulated the government to enhance the enabling environment for private sector and product development by establishing codes of practise and standardisation for solar systems. Close collaboration between government and non-governmental organisations has also contributed to growth in some countries, such as Zimbabwe and Senegal. Even in countries with significant penetration of solar home units, their initial cost is very high in comparison with income levels. Thus, penetration rates could increase substantially if costs continue to decline.

More favourable tax regimes could also help increase market share. At present, PV units are subject to high taxation in some countries — for example, a 15% import tax and 20% Value Added Tax (VAT) in Kenya and a 15% sales tax in Zimbabwe. However, in Senegal and most Sahelian countries, import and other taxes were removed in 1994 as a means of boosting the dissemination of these units (INFORSE, 1996-98).

Technical constraints have impeded widespread penetration in some countries. In Senegal and some other countries, technical back-up programmes such as specialised maintenance facilities are introduced in addressing this problem.

The installed PV units are currently estimated to replace 0.8 Mto in the petroleum sector savings equivalent to 730 tC if that power were supplied by oil-fired plants and even more if by coal-fired plants, as would be the case for Zimbabwe and South Africa. The penetration of these units is growing very fast — largely through the initiatives of the private sector — with a 5% annual increase predicted.

Solar water heaters are widely used in countries of eastern and southern Africa for domestic purposes. Some technical problems — such as poor water quality, especially in remote areas, resulting in tube clogging; poor manufacturing and marketing; and failure to effectively match needs with supply and social habits — have been reported. These contribute to the poor penetration of these technologies. However, solar water heaters are being used successfully in both urban and rural areas of Botswana, with estimated energy savings of 10 MW. This typically replaces electricity generated from a coal-fired plant or, in lower-income households, firewood. Policy, institutional, and financial initiatives by the government of Botswana in compelling the installation of water heaters in educational institutions, setting up promotional rural institutions, and providing loans for RETs are contributing significantly to the dissemination of these technologies. Also, an estimated 2000 solar water pumping units have been installed in commercial farms in Namibia, South Africa, and Kenya, with smaller numbers in other African countries (Karakezi and Ranja, 1997).

The use of ethanol has yielded meaningful savings of imported petroleum in some countries. The most successful has been Zimbabwe, which began blending gasoline with 14% ethanol in 1980 for energy security reasons related to international sanctions. This plant produces about 40 million litres of ethanol annually (Scurlock et al., 1991). Because the ethanol is produced from sugarcane, a renewable resource, this amounts to a saving of 352,000 barrels of oil a year, or 0.045 MtC in avoided emissions.

The use of agricultural and forestry wastes to produce power has been practised in Africa for more than 20 years. However, with only a few exceptions — including Mauritius, where bagasse plants supply 12–13% of the nation's electricity — most of these wastes are recycled within plants to create electricity for their own consumption. In over 60% of Africa's 53 countries, electricity is produced from waste and used within sugar plants. According to 1987 records, African sugar production amounted to 72 million tonnes of sugar that year. It takes 25–30 kWh of in-house electricity to produce 1 tonne of sugar (Pennington et al., 1997). Thus, using the lower figure, 1800 GWh was produced and consumed, essentially replacing fossil fuels. Also, potential exists for producing extra power for use by the national grids of the different countries. In Mauritius in 1996, 84 GWh of surplus power produced from bagasse was exported to the national grid. Other agro-based industries that use wastes to produce in-house electricity are palm products and wood-milling plants. In Sierra Leone, a 1.5-MW wood-fired plant provides electricity for consumers in the area.

In general, African countries have been slow to utilise passive solar systems to improve energy efficiency in homes and institutional buildings compared to other parts of the world. However, passive solar designs have been tested in South Africa and Chad. In South Africa, significant carbon emission savings were achieved in new homes built in response to a government policy supporting energy-efficient, low-cost housing. The savings amounted to a total of 1.75 MtC/year, based on the assumption that their heating/cooling and cooking needs would otherwise have been supplied by oil-fired plants and coal-fired plants together (Abron, 1997).

OTHER GHG-LIMITING INITIATIVES

The overall performance of power utilities has been poor in many African countries. However, there have been some substantial improvements (Davidson, 1994). Among these are a reduction of transmission and distribution losses in Mali due to the halted construction of a 5-MW power plant, and the introduction of housekeeping measures in the power plants of Tanzania, eliminating their need for a 10% expansion of their plant capacity.

Some coal-fired power utilities on the continent are becoming more efficient, resulting in a reduction of coal consumption and an associated reduction in GHG emissions. The case of South Africa, which uses the majority of such plants, is shown in Figure 5. This improvement in plant performance is a result of optimised combustion, improved boiler designs, and cooling water treatment, leading to improved turbine efficiencies.

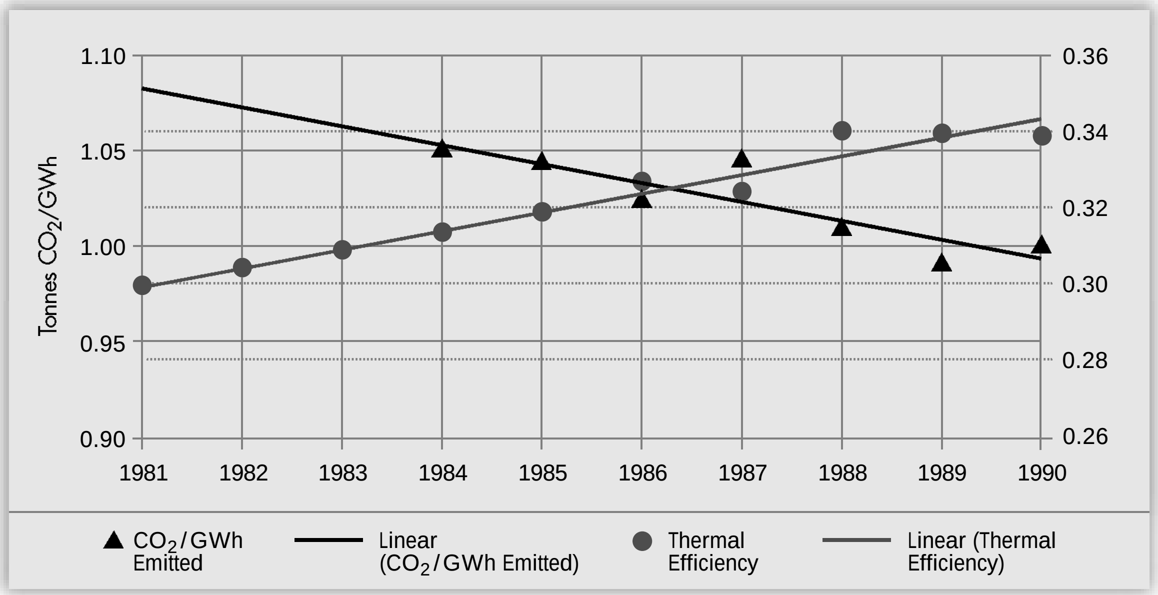
The present price structure of fossil fuels in developing countries is a result of a complex configuration of taxes for revenue collection, and incentives and subsidies for equity and social reasons. Since the 1980s, some countries have embarked on varying price reforms that resulted in a significant drop in carbon emissions. Between 1990/91 and 1995/96, for example, fossil fuel subsidies in the 14 developing countries that accounted for 25% of global emissions declined by 45%, from US$60 to US$33 billion; for the same period, subsidies in the OECD declined only by 20.5%, according to the World Bank. South Africa is one case in point. As a result of a 119% increase in coal prices between 1991 and 1994, the equivalent of 3.36 MtC of CO_2 emissions were avoided (Reid and Goldemberg, 1997).

Some African countries, such as Tunisia and Ghana, are using combined cycle plants for power production, leading to carbon savings because of reduced fuel consumption. Senegal, Kenya, and South Africa are also making use of compact fluorescent lamps in their cities, with resulting power savings, which bring about a reduction of GHG emissions.

African countries are implementing a variety of measures to cope with the challenges of the transport sector — including road congestion and inadequate supply of services. Côte d'Ivoire, for instance, has invested in a transport programme including dedicated lanes for buses, compact commercial vehicles, and transport fees. Ghana has made progress in producing non-motorised systems, according to the World Bank. Improved telecommunications in Africa have resulted in reduction of travel. On the whole, all these measures are resulting in avoided GHG emissions because of the fuel and power use they replace.

South Africa's power utility, ESKOM, is expected to introduce electric cars in the country. Tests have shown that the car will travel 100 km, using 25 kWh at a cost of US$1.35 and US$0.54 in peak and non-peak hours, respectively, compared to a petrol engine vehicle that would require 10 litres costing US$5.06. Also, the car has demonstrated better efficiency — 22% compared to 10% for petrol cars — with an associated reduction in GHGs and other pollutants.

FIGURE 5: Enhanced Thermal Efficiencies and CO_2 Emissions (ESKOM - South Africa)



CONCLUSIONS

The establishment of new partnerships between Annex I and non–Annex I Parties offers potential to reduce the threat of global warming. However, innovative approaches may be needed to strengthen these partnerships. Their potential can be realised through genuine co-operation between Annex I and non–Annex I Parties, and recognition of the latter's urgent need to achieve a threshold of development. Annex I countries can accelerate the current progress by African and other developing countries in slowing down GHG emissions by providing more access to financial and technological resources.

REFERENCES

Abron, L., December 1997: Housing as if people mattered: The story of Kutlwanong, South Africa. International Institute for Energy Conservation (IIEC) Report to COP-3 of UNFCCC, International Institute for Energy Conservation, Washington D.C.

Acker, R. and Kammen, D.M., 1996: The quiet energy revolution. Energy Policy, **24**(1), 81-111.

African Development Bank, 1997: Annual Report of African Development Bank: Abidjan, Côte d'Ivoire.

BCAS/Pacific Institute, 1997: A New Initiative for North-South Dialog on Climate Change: Good Practices, Technology Innovation and New Partnership for Sustainable Development. Bangladesh Centre for Advanced Studies and Pacific Institute for Studies in Development, Environment and Security. Dhaka, Bangladesh.

Bolin, B., 16 January 1988: The Kyoto negotiations on climate change: science perspective. Science, **279.**

B.P., 1996: BP Statistical Review of World Energy 1996: British Petroleum, England.

Davidson, O. R., January-March 1994: Challenges and prospects for power development in Africa. UNEP/Industry and Environment, **17**(1).

Lenssen, N., and C. Flavin, 1996: Sustainable energy for tomorrow's world. Energy Policy, **24**(9), 769-781.

Flavin, C. and S. Dunn, November 1997: Rising sun, gathering winds. Worldwatch Paper 138.

GEF, November, 1996: Quarterly Operational Report. Global Environment Facility, World Bank.

INFORSE, 1996–98: Sustainable Energy: Newsletter for INFORSE. International Network for Sustainable Energy, Copenhagen, Denmark.

Karakezi, S. and T. Ranja, 1997: Renewable energy technologies in Africa. African Energy Policy Research Network (AFREPREN). Zed Press.

Pennington, M., L. Lacrosse, and A.D. Gonzales, 1997: Cogeneration using wood and agro-industrial residues in South-east Asia. In: The World Directory of Renewable Energy. James Press, 130-132.

Reid, W.V. & Goldemberg, J., July 1997: Are developing countries already doing as much as industrialised countries to slow climate change? World Resources Institute Climate Protection Initiative. Climate Notes.

Scurlock, J., A. Rosenschein, and D. Hall, 1991: Fuelling the Future: Power Alcohol in Zimbabwe. ACTs Press, Nairobi, Kenya.

Shackleton, L., S. J. Lennon, and G. R. Tosen (eds.), 1996: Global climate change and South Africa. Environmental Scientific Association, Cleveland, South Africa.

UNFCCC, 1997: Kyoto Protocol to the United Nations Framework Convention on Climate Change, COP-3, FCCC/CP/1997/L.7/add.1 Bonn, Germany.

WRI/UNEP/UNDP/World Bank, 1998: 1988–99 World Resources: A Guide to the Global Environment: World Resources Institute, United Nations Environment Programme, United Nations Development Programme and the World Bank, Oxford University Press, New York.

World Bank, 1995: World Development Report, 1995: World Bank, Oxford University Press, New York.

CHAPTER 6

Carbon dioxide emission trends from the United Kingdom

Nick Eyre
Eyre Energy Environment
Leeds, UK

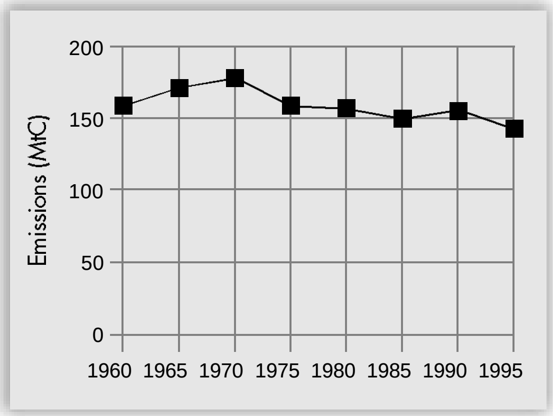
SUMMARY: Carbon dioxide emissions in the United Kingdom have fallen for 25 years, and carbon intensity — carbon emissions compared to overall productivity of the economy — has fallen even more steeply. This reduction in carbon intensity has been achieved by a combination of decarbonisation of the energy system (mainly through the use of natural gas) and substantial improvements in energy efficiency. Use of natural gas for power generation has been the biggest factor in recent years. However, energy efficiency improvements in households and particularly industry have been more important over a longer period. The changes have occurred due to a combination of factors, in particular as part of a well-known trend towards decreased energy intensity in developed economies. Some government policies have contributed, but policies designed primarily to address climate change have not been important contributors. Further reductions in emissions are possible without any economic penalty, notably by adopting already cost-effective energy efficiency measures, using new renewable energy sources, and strengthening public transport provision. In many cases, there are social and institutional barriers to these changes, and therefore further policy changes are required.

INTRODUCTION

Subject to ratification of the Kyoto Protocol, all Annex I countries will have legally binding commitments to limit emissions of greenhouse gases in the period 2008-2012. In most cases, emissions will be required to decrease from 1990 levels, so the commitments are more constraining than the voluntary agreement to stabilise emissions at 1990 levels by 2000 made at the Rio conference in 1992. However, the track record of Annex I countries on emissions stabilisation is generally weak, and few countries are expected to fulfil the Rio agreement. The UK is one of the few that has reduced its carbon dioxide emissions in recent years. It is therefore an interesting case study of CO_2 baseline emissions in a developed country. The policies and technologies used may also provide information for sustainable development in developing countries and the operation of the Clean Development Mechanism (CDM).

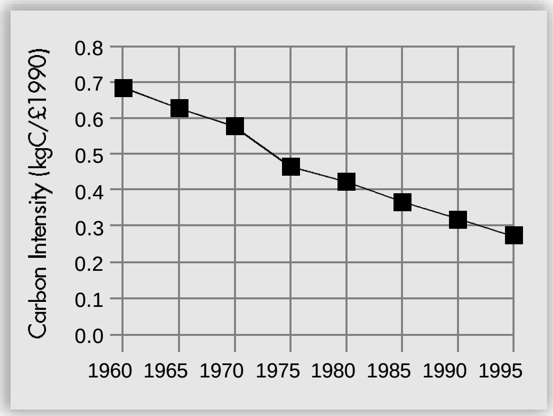
As shown in Figure 1, CO_2 emissions in the UK have been falling

FIGURE 1: UK Carbon Emissions, 1960-1995



Source: Author's calculations based on UKDTI, 1997a.

FIGURE 2: UK Carbon Intensity of the Economy, 1960-1995



Source: Author's calculations based on UKDTI, 1997a.

for 25 years. Since the population has been broadly stable over this period, carbon emissions per capita show the same declining trend, although the present absolute level of about 2.7 tonnes/year remains well above the global average. The carbon intensity of the economy (carbon per unit of GDP) has fallen very substantially, as shown in Figure 2. Decarbonisation of the energy system, structural change, and technical efficiency gains have all contributed, as discussed below.

Policies to address the United Nations Framework Convention on Climate Change (UNFCCC) commitments were first adopted by the UK Government in January 1994; they were revised in December 1995, and again in February 1997. The Labour Government, elected in May 1997, is now undertaking a major revision to address both its own target of a 20% reduction in CO_2 emissions by 2010 and the six-gas basket commitment of a 12.5% reduction arising from the European Union's recent agreement on sharing its Kyoto commitment. A consultation document on the revised policy was published in November 1998.

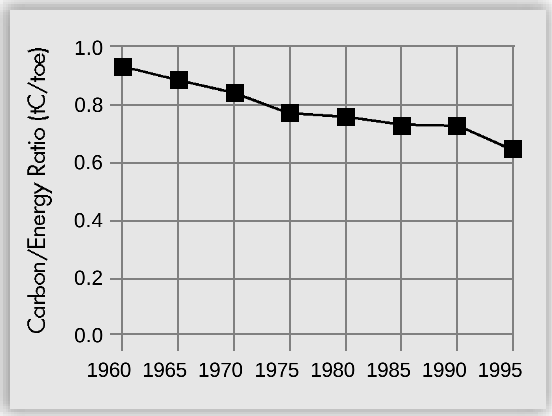
Analysis of the UK's relative success indicates that emissions reduction has been achieved without radical, climate-driven policy changes. The original Climate Change programme (UKDOE, 1994) identified emission reduction measures of 10 million tons of carbon (MtC) — about 6% of total UK emissions. The measures were largely based on voluntary initiatives in households, industry, and the power sector, with fiscal measures confined to an increase in road transport fuel tax and the introduction of value added tax (VAT) on household fuels.

Some of the policies envisaged have not been implemented or have been unsuccessful:

- Voluntary commitments by business leaders have not been fully reflected in actions — monitoring of progress has been incomplete and some targets have not been met
- Household VAT increases to the full rate, originally proposed, of 17.5% were not adopted
- Funding of the Energy Saving Trust (a joint venture of the government and energy utilities) has been far lower than initially planned.

Nevertheless, emissions reductions have been achieved. Comparison of the later Climate Change programmes (UKDOE, 1995; UKDOE, 1997) with the initial targets indicates that policy changes for other reasons, particularly in the electricity sector, have been important, along with the continued longer-term trends in UK energy use. The remainder of this section analyses these long-term trends on a sectoral basis. Section 2 looks in more detail at the relevant past policies and the driving forces behind them. Section 3 outlines the programmes involved, and Section 4 identifies the future policies and programmes the UK Government is considering to reach its targets and honour its commitments. Section 5 draws some provisional conclusions from the UK experience for the rest of the world.

FIGURE 3: UK Carbon Intensity of Energy, 1960-1995



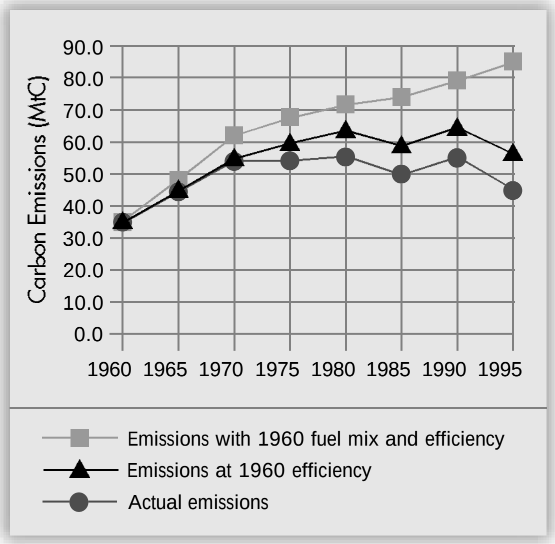
Source: Author's calculations based on UKDTI, 1997a.

The analysis is confined to emissions from commercial energy use, as land use changes are of minor importance in a densely populated developed country like the UK. In order to undertake the analysis as transparently as possible, carbon intensity of the energy system is considered first, followed by energy intensity of the economy, broken down into the main energy-using sectors — manufacturing industry, services (commercial and public), households, and transport.

Carbon Intensity of the Energy System

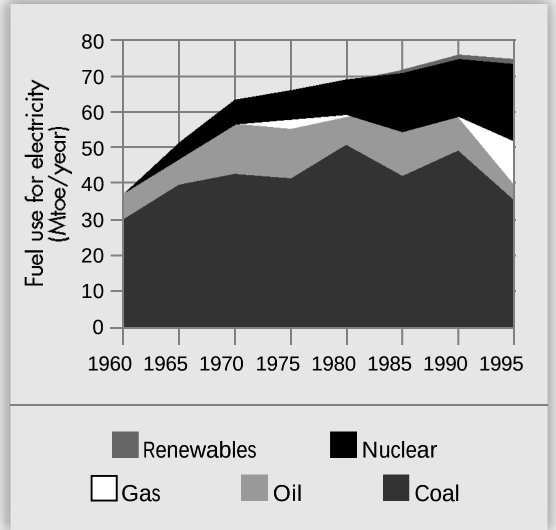
The carbon intensity of the energy system depends on the use of non-carbon fuels (nuclear and renewables) and the relative importance of the different fossil fuels, especially natural gas, which has a low carbon intensity. In the UK, renewable fuels are relatively unimportant at present (about 1% of primary energy). The use of nuclear power has grown significantly, but is now broadly stable at 10% of primary energy. The use of natural gas, largely to displace coal, has been the main feature of the overall energy balance, rising from zero in the 1960s to over 35% today. The effect on the carbon/energy ratio of the energy system is shown in Figure 3.

FIGURE 4: UK Power Sector Carbon Emissions, 1960-1995



Source: Author's estimates based on UKDTI, 1997a.

FIGURE 5: UK Power Sector Fuel Mix, 1960-1995



Source: UKDTI, 1997a.

For many years, natural gas was used mainly for heating. In the household sector, natural gas now supplies 68% of final energy. However, the main trend in recent years (expected to continue into the future) has been penetration of the electricity sector. Indeed it is the electricity sector that has shown the biggest changes in carbon intensity.

Electricity production has grown in the UK over the whole of the modern era, although in recent years the growth has been less marked than in most other developed countries because of the availability of relatively cheap natural gas, which is widely used for heating. Between 1960 and 1995, total electricity use rose 150%, from 129 terawatt hour (TWh) to 318 TWh, yet carbon emissions changed by only 32%.

Figure 4 shows that this was partly due to increased efficiency in fossil-fuelled generation (29% to 38%), but mostly to changes in the fuel mix. Figure 5 shows the changing mix of fuels in power generation — a growth in nuclear capacity, the recent entry of gas into the power market, and a small renewables programme — at the expense of reduced coal and oil burn.

Electricity sector emissions are currently falling, and the trend is expected to continue. There is a preference for combined cycle gas turbines (CCGT) in new investments. The government is concerned to halt this "dash for gas," because of its effects on coal-mining communities, and recently has confirmed an effective moratorium on new CCGTs. However, a renaissance of coal is very unlikely with gas at current prices. The net effect of the moratorium may be to increase interest in combined heat and power (CHP) and renewables for new entrants to the power market. This would further reduce carbon emissions.

Overall Energy Intensity

The energy intensity (energy use per unit of total GDP) and electricity intensity (electricity use per unit of total GDP) of the UK economy have followed different trends in recent years. Figure 6 shows the values normalised to 1960 levels. Energy intensity has declined fairly steadily, although more rapidly in the period marked by the oil crisis. Electricity intensity rose until 1970, but has subsequently fallen.

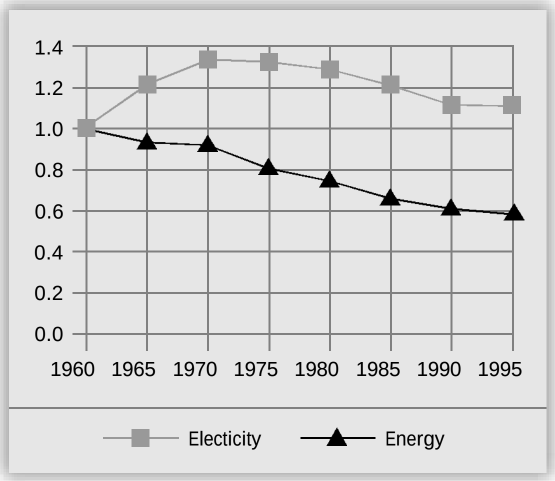
For a full understanding of the trends, it is necessary to look at a sectoral level. Figure 7 shows the sectoral energy intensity (sectoral energy use per unit of total GDP) for the four main energy-using sectors (households, services, industry, and transport). Figure 8 shows a similar breakdown for electricity intensity (excluding transport, where electricity use is small). In both cases, intensities have decreased most (or increased least) in the industry sector, followed by household use and the service sector. Only in the transport sector has energy intensity grown.

Industry

The energy intensity of the manufacturing industry has declined steadily and substantially in recent years. Electricity intensity has fallen since 1970, but less substantially. The energy intensity trend is so strong that industrial energy consumption has fallen significantly despite economic growth; industrial electricity consumption has risen slowly. This energy intensity reduction may be attributed to three broad causes:
- declining share of GDP for which manufacturing accounts in the UK economy
- industrial structural change — that is, the relative decline of energy intensive sectors
- technical efficiency improvements.

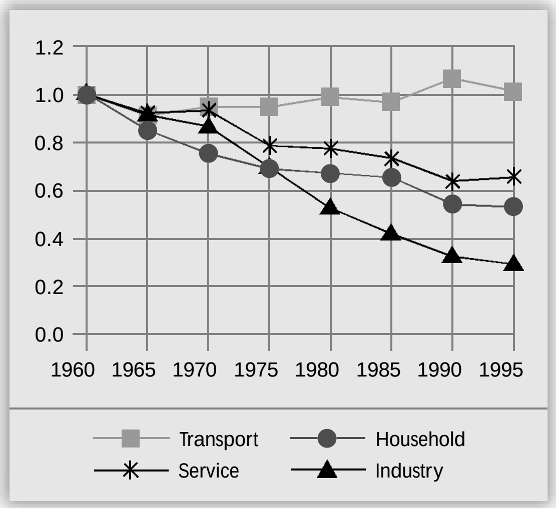
The relative decline of manufacturing and the restructuring within it are each estimated to have contributed 10% to the reduction in energy intensity since 1970 (based on UKDTI, 1997b). The remaining effect is a reduction in energy intensity within each industrial sub-sector, which has contributed about a 50% reduction over the same period. Some of this may be a change in product mix because of higher "added value" products, but the majority reflects technical

FIGURE 6: UK Energy and Electricity Intensity, 1960-1995



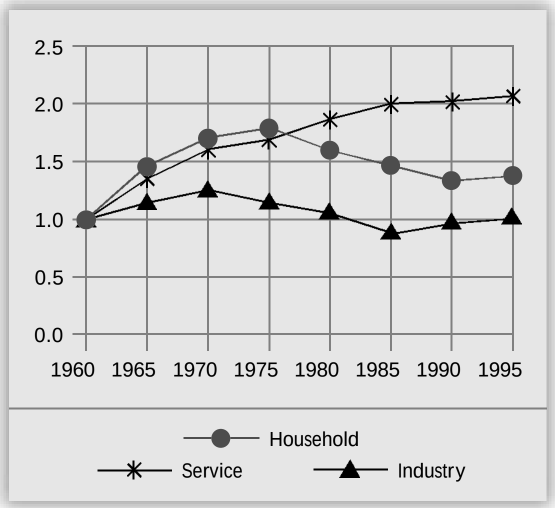
Source: UKDTI, 1997a.

FIGURE 7: UK Energy Intensity by Sector, 1960-1995



Source: UKDTI, 1997a.

FIGURE 8: UK Electricity Intensity by Sector, 1960-1995



Source: UKDTI, 1997a.

efficiency improvement.

New investments generally have significantly higher efficiency and lower emissions than older plants. This is true for almost all processes. Energy-intensive sectors and large companies generally make more energy efficient investments, but small and medium-sized enterprises often lack the necessary information and/or expertise. Key technologies are those relevant across all sectors — for example, efficient boilers, CHP, high-efficiency motors, and motor controls.

In addition, carbon intensity can be affected by changes in fuel mix, in particular the greater use of natural gas. However, in recent years this has changed relatively little, from 37% of fossil fuel use in 1980 to 44% now.

Service Sector

In the service sector, energy intensity has declined, but less rapidly than in the industrial sector. The value of service sector output as a fraction of total GDP has risen, but has shifted towards lower energy intensity sub-sectors, such as commerce. The overall effect is that energy use in the service sector has risen slowly. Electricity intensity has risen, largely reflecting the shift to the higher electricity consuming sub-sectors (offices, retailing, etc.). There has therefore been a large increase in electricity use in the service sector. The share of natural gas use has also risen. Lighting makes a particularly large contribution to energy use in this sector. New investments generally have a higher efficiency, owing to the use of high-efficiency tubes, electronic ballasts, reflective luminaries, and control systems. A key issue in commercial office energy efficiency is the use of air conditioning. In the cool temperate climate of the UK, building design can give comfortable conditions without the use of space cooling, although most "prestige" office developments still use energy-intensive air conditioning.

Households

Energy intensity in the household sector has fallen continuously in recent years, at a rate a little slower than economic growth, so energy use has risen a little. Electricity intensity grew substantially until 1975, but has subsequently fallen with saturation of the major electrical appliances.

The overall changes in fuel use balance comfort increases against efficiency improvements. Achieving adequate internal household temperatures requires space heating for seven to eight months of the year in the climate of the UK, so space heating is the dominant end-use in this sector (57%). Water heating is responsible for another 25% and is usually provided by the same boiler (UKDTI, 1997b).

Internal temperatures have increased, largely as the result of central heating, which is now present in over 85% of households (UKDTI, 1997b). This form of heating is substantially more efficient than the older technologies it replaced, usually open fires, and the change to cleaner technology was partly driven by concerns in the 1950s and 1960s about severe urban air pollution. However, up to 30% of UK households still live in indoor temperatures below those recommended by the World Health Organisation, because of the combination of a housing stock that is poorly insulated by Northern European standards and increased income inequality. New dwellings have much improved insulation compared to existing houses, but the housing stock is remarkably old — 45% of homes are more than 50 years old. Although there have been significant programmes of retrofit insulation, many homes still fall short of adequate standards.

Electricity efficiency shows less improvement. Both lighting and appliance efficiency remain well below best practise, as neither compact fluorescent lighting nor high-efficiency appliances have a large market share.

In addition, the balance of fossil fuel use has changed. Natural gas is available to most households and now accounts for 85% of the household fossil fuel market. Emissions have therefore fallen continuously, despite the growth in energy use (NAEI, 1997). Further significant penetration of gas is unlikely, as the remaining consumers are largely in rural areas, where connection to the gas grid is uneconomic.

Some trends point towards new high-efficiency investments. Condensing boilers offer major potential improvements in heating efficiency, but still have a low market share. Compact fluorescent lights with an 80% efficiency improvement have been marketed for several years. Sales are still low because of high initial costs, but are increasing, and 30% of households now have at least one lamp (EST, 1998). Efficient appliances have been slower to enter the market than in some other European countries.

Transport

Figure 7 indicates that transport has been the only sector in which energy intensity has risen in the UK in recent years, although there are now signs that the trend is slowing and may be reversed. Most of the energy use is in road transport, although air transport energy use is growing rapidly (but the emissions are not included in statistics for UNFCCC purposes). The dominant cause of rising energy intensity has been that road transport activity, both passenger and freight, has risen faster than GDP (UKDTI, 1997b). Although there has been an increase in vehicle energy efficiency, this has been rather limited and far less than what is technically possible. Improvement in energy efficiency has been largely offset by the relative decline of more efficient modes — notably buses.

The fuel mix has changed little: use of diesel, with generally lower CO_2 emissions (per kilometre travelled) than petrol, has increased, but alternative fuels, such as gas, electricity, and biofuels, have not penetrated the market significantly.

Rising energy intensity gives the transport sector the fastest emissions growth of all sectors in the UK economy, making it the only sector in which CO_2 emissions have risen in recent years.

PAST POLICIES AND POLICY DRIVERS

The changes in carbon intensity have been due to a complex set of trends and policies. Although some policies have been influenced by the climate change agenda, most of the important changes have derived from polices related to other government goals. For the 15-year period from 1982 to 1997, UK Government energy policy emphasised minimal intervention and the benefits of free markets. Since the election of a Labour Government in May 1997, other issues — environmental, industrial, and social concerns — have been given greater emphasis. Many policies are under review and regulation is likely to increase, but the trend towards competitive markets will continue.

Power Generation

The dominant theme of the 1990s in the UK power sector has been market restructuring. The industry was largely privatised in 1990, although the nuclear sector remained in public ownership for several years, and the biggest nuclear liabilities remain in the public sector. At privatisation the industry was largely unbundled — in England and Wales, three major generating companies were created, with a separate transmission grid company and 15 regional electricity companies responsible for distribution and supply. In Scotland and Northern Ireland, vertical integration was preserved. Competition has increased steadily. A range of new entrants use largely CCGT generation. In supply, the threshold for competition has been reduced to customers with a maximum demand of 100 kilowatts, and from late 1998 the market will be fully open to competition down to the household consumer.

Restructuring has had some effect on prices, particularly in the market segments open to competition, although there are complaints that competition is not fully effective because of the small number of large generating companies. The government is reviewing regulation of the sector to ensure a greater focus on consumer interests. Declining prices inevitably place upward pressure on demand and emissions. However, for many categories of customer — in particular, householdsand energy intensive industry — demand is rather price inelastic (UKDTI, 1997c) and therefore the effect is not large.

The main impact of restructuring on emissions has been beneficial. Both new entrants to the generating market and the existing companies had an incentive to use low-cost gas supplies to develop new capacity rapidly. Gas-fired generation has taken a 30% market share, with more capacity under construction. The major loser from this “dash for gas” has been the UK deep-mined coal industry, already in difficulty in the aftermath of a major industrial dispute in 1984 and 1985. Legislation to implement international acid emission reduction agreements has placed further constraints on coal use in power generation, as most UK plants have not invested in desulphurisation equipment.

The effect of the “dash for gas” on emissions has been substantial, reducing UK emissions between 1990 and 1997 by about 14 MtC (8% of UK total emissions). Without this change, UK carbon dioxide emissions would not have fallen since 1990. However, the common perception that the UK would have failed to meet its target of stabilising all greenhouse gas emissions is incorrect. When non-CO_2 greenhouse gases are included, UK emissions would still have fallen, even without the “dash for gas.”

Other, even cleaner generating options have benefitted from restructuring, although to a lesser extent. The introduction of competition in the gas industry has given industrial users access to cheap gas supplies. This situation, coupled to the increasing ability to sell power off-site, has made combined heat and power (CHP) more economically attractive, especially in industrial sectors with large heat loads, but increasingly also to other, smaller users, such as hotels and hospitals.

Renewable energy has also benefitted from the operation of the Non-Fossil Fuel Obligation (NFFO) in the restructured electricity market. NFFO was originally introduced to protect the nuclear generating industry when financial markets balked at its privatisation. It allowed the government to specify amounts of electricity to be purchased from nuclear generators, but because EU competition rules prevent general subsidies, the law was formulated in terms of protecting diversity and stimulating non-fossil fuel generating options, and therefore also created a protected market for electricity from renewable sources. Support for nuclear power under NFFO was phased out in 1998, so that renewables are now the sole beneficiary of the arrangement. Capacity is acquired by periodic orders in which renewables from specified sources bid for contracts. The major beneficiaries to date have been energy from wastes and onshore wind power. NFFO is widely regarded as being successful in securing renewable capacity at low and declining costs. However, as a mechanism, it has been less successful at increasing capacity than the minimum price regimes used in some other countries, such as Germany and Denmark (Mitchell, 1998). The five NFFO orders to date (and similar orders in Scotland and Northern Ireland) are expected to secure about 1500 MW (approximately 2.5% of UK total capacity).

Manufacturing and Services

The policy of minimum government intervention by the previous UK Government applied to industry and commerce as well as the electricity sector. Therefore, use of instruments such as regulation has been limited. In addition, low tax policies mean that energy taxes and other economic instruments have not been used. Support for energy efficiency in the business sector has been concentrated on information and exhortation, with modest financial assistance for research and technology development. These programmes were introduced originally to reduce reliance on energy imports and improve industrial efficiency, but are now driven by environmental concerns.

The significant improvements in business energy intensity have therefore resulted mainly from forces other than direct government intervention. Particularly in the late 1970s and early 1980s, the combination of economic recession, currency strength (supported by oil revenues), and tight monetary policy led to rapid industrial restructuring with decline of heavy manufacturing and growth of services. The UK now has a low share of energy intensive industry compared to other Annex I countries, and those activities that survived the recessions of the 1980s tended to be the more energy efficient. Many of the UK's economic strengths are in the service sector, where energy intensity is low.

Many of the same pressures apply to the public sector, where restraints on revenue have produced incentives to maximise energy efficiency. On the other hand, very severe constraints on public capital expenditure have limited investment opportunities for greater energy efficiency in public services, such as education and health.

Households

Since the restructuring of the UK gas and electricity industries, the main policy emphasis has been on low prices. The energy sector regulators have been largely independent of government and have paid little attention to environmental issues. They have concentrated on the introduction of supply competition and the use of price-cap regulation, neither of which has given energy suppliers much incentive to encourage end-use energy efficiency. Therefore the barriers to energy efficiency, especially in the household sector, remain high.

Under pressure from non-governmental environmental organisations, energy sector regulation law was amended to allow for energy suppliers to raise prices specifically to fund energy efficiency programmes. However, regulators have been reluctant to deviate from their free-market instincts to use these mechanisms, despite proven cost-effectiveness where they have been used. The funding for demand-side management activities in supply industries has therefore been small.

The one attempt to raise energy taxes in the household sector has largely failed. A proposed imposition of VAT would have raised taxes on household fuel from zero to the full rate of 17.5% in two stages. Following vigorous public opposition, the second stage was defeated in Parliament, leaving a rate of 8%, which was subsequently reduced to 5% by the incoming Labour Government. There is now little prospect of any household energy tax being publicly acceptable.

The reason for public opposition to energy taxes in this sector is the phenomenon of low indoor temperatures in poorer households described earlier, usually known in the UK as "fuel poverty." This came to the fore as a political issue following the oil shocks of the 1970s. To some extent, it has been alleviated since the mid-1980s by falling prices, especially for gas. However, increased income inequality and the poor condition of much of the housing stock ensure that it remains an important issue. One effect has been the use of government funding to support social programmes to improve household energy efficiency (see also section on households, below).

Regulation of building practise includes higher efficiency standards for new buildings, but stock turnover rate is very low; therefore, the effect of this policy on overall energy efficiency in the sector is limited. Environmental pressures and European single market regulations have produced increased use of labelling and standards for major appliances.

Transport

Traditional emphasis in UK public policy has been on support for car ownership and use — what a former British Prime Minister described as the "great car economy." A key element of this was the "predict and provide" approach for new roads, in which capacity was expanded to meet assumed demand growth. Since the early 1990s, the approach has become untenable because of the combination of public expenditure constraints and widespread opposition to the environmental effects of road building. It is now widely accepted that car use will have to be constrained to deal with growing congestion and pollution. The government has produced a major review of transport policy, which will introduce greater emphasis on alternatives to the private car.

Deregulation in the transport sector has been emphasised, with the privatisation and liberalisation of bus and train services. This has produced some benefits on routes with high utilisation and opportunities for a range of profitable operations. However, problems have also arisen:

- Unprofitable public transport routes have been abandoned.
- Public authorities have a limited ability to regulate quality, safety, and accessibility.
- Investment in rail and bus infrastructure has been low.
- Integration in transport networks has diminished.

The recent government review will reverse the trend of deregulation.

The most important attempts to constrain growth of demand for road transport have been with fuel taxes, which are at typical European levels (about US$0.7/litre). Like any tax, this approach is not universally popular. However, it does not provoke the adverse reaction seen in the US. The Labour Government has continued the policy of raising fuel taxes in real terms every year and is now committed to a 6% real increase annually until 2002. Other economic instruments will now be introduced. No policies are currently in place to regulate vehicle efficiencies, although this is now under discussion at an EU level. (Future policies and instruments are discussed further in the section on transport below.)

CURRENT PROGRAMMES AND PROJECTS

The ideological orientation of the previous UK Government led to a preference for relying to a large extent on the market rather than intervening directly in the economy. The number of central government programmes is therefore rather limited.

At the level of local government, however, many Local Agenda 21 actions seek to involve citizens in environmental actions and promote sustainable development. The development of these activities is inevitably patchy, as they rely on the enthusiasm of citizens and the commitment, funding, and effectiveness of local administrations, which have limited powers. While many of these initiatives exemplify good practise and innovation, they remain largely uncoordinated, and are often badly financed and ineffective.

The UK Government now rejects a simplistic division between state regulation or control, on the one hand, and free markets without government intervention, on the other. Increasingly, it emphasises the use of public/private co-operation for both investment and programme management. The role of the public sector as partner in and facilitator of private actions is therefore likely to increase.

Power Generation

Market forces and actions by economic regulators to increase competition in the gas and electricity sectors produced rapid investment in CCGT by privatised utilities and independent power producers without formal government support. Despite a moratorium on new CCGT (see section on power generation, above), the longer-term trend towards using gas and CHP is likely to continue. The efficiency of generation will continue to rise and the carbon intensity of the overall fuel mix to fall. New power projects using coal, oil, or nuclear fuels are unlikely.

Support for renewables via the NFFO is seen as broadly successful. Although the growth is limited compared to that in some other European countries, the mechanism is likely to be retained to reach the Government’s target of 10% renewable electricity by 2010.

Manufacturing and Services

Programmes in industry and commerce are currently limited to information, exhortation, and some support for innovative energy efficiency technology. The government plays no explicit role in influencing fuel choice.

In the “Making a Corporate Commitment” campaign, business leaders committed their companies to specified goals for energy efficiency. Although there are over 2000 participants and the commitments receive a high profile when they are made, effective monitoring or reporting has not occurred, and there are no sanctions for failure. The programme is therefore only a limited success.

The Energy Efficiency Best Practise Programme has a wider scope and is generally acknowledged to be successful, although its scale is rather limited. It supports a range of activities, including research and technology development, demonstration, and benchmarking. The activities are integrated with detailed and targeted information programmes.

A move toward negotiated energy efficiency agreements between government and industrial sectors is beginning. Such agreements are common in some other European countries — notably the Netherlands and Germany. The only agreement in place so far in the UK is with the Chemical Industry Association, whose members have agreed to improve energy intensity by 20% between 1990 and 2005, with government providing technical assistance for smaller companies. More agreements along similar lines are under negotiation.

In addition, there are some subsidised energy efficiency programmes for small businesses under the Standards of Performance schemes (as discussed in the next section).

Households

The Home Energy Conservation Act (HECA), passed in 1995, requires local authorities to develop energy conservation plans for the housing stock with targets for energy efficiency improvements of 30%. Some interesting and innovative pilot projects have been begun under the HECA Action programme. However, the investment required to achieve a 30% efficiency improvement is many billions of dollars — far outside the scope of local government budgets. Alternative funding arrangements are required if the HECA targets are to be achieved. Potential sources include the energy supply industry and private housing finance (see next section on households, below).

The Home Energy Efficiency Scheme (HEES) provides basic home insulation measures for low-income households. It is funded by general taxation and currently has an annual budget of approximately US$125 million. The measures supported are restricted to approximately US$500 per household, which prevents installation of the full range of effective measures in many homes. The operation of HEES is being reviewed as part of the government’s targeting of fuel poverty.

The Energy Savings Trust is a joint venture owned by government and energy utilities. It runs a range of programmes. These include information, subsidy, and market transformation programmes funded by a government grant (currently about US$30 million annually). In addition, the Energy Savings Trust oversees and manages some of the programmes funded by regulatory requirements in the electricity industry — the Standards of Performance schemes — under which electricity utilities are required to invest in energy saving (currently about US$40 million annually). The Energy Savings Trust programmes have been shown to be highly cost-effective, and they are being developed to meet the requirements of competitive energy markets. However, the current scale of investment is too small to have a very large effect on UK household energy efficiency.

Transport

Since the abandonment of “predict and provide” as a roads infrastructure policy, government spending has shifted away from road building to more environmentally friendly schemes. Public transport infrastructure projects have been initiated in several major cities, and the government is seeking public/private partnerships to upgrade the rail network. In addition, support for subsidised bus services in rural areas has increased slightly. Transport policy is in a state of flux, and government’s future plans were recently announced (as discussed further below).

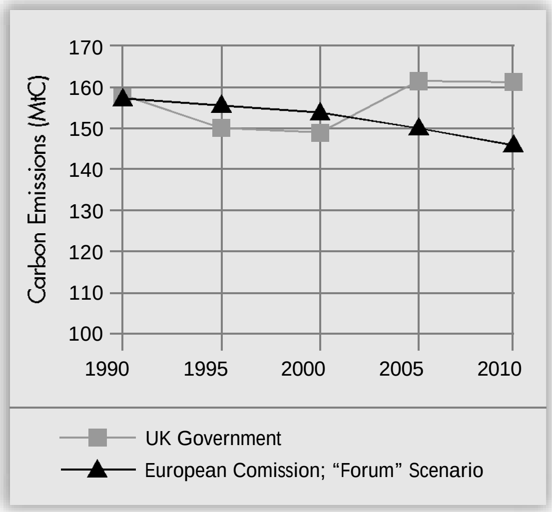
Some initiatives support alternative fuels, particularly the Energy Savings Trust’s Powershift programme. The attention is concentrated on gas and electricity; biofuels are generally assumed to be better used for power generation in the UK. In addition, the government has established a Clean Vehicle Task Force to look at emissions reduction.

Future UK policies and programmes will be influenced by the commitments under the Kyoto Protocol and the UK Government's own more ambitious target. Current UK Government energy projections indicate that without further policy action, carbon emissions will begin to rise again in the early years of the next century, surpassing 1990 levels by 2010. A projection resulting from mainstream assumptions about prices and economic growth is shown in Figure 9 (UKDTI, 1995).

This projection is widely believed to under-estimate the continuing trends towards decarbonisation and energy efficiency. The projection is based on the assumption that energy use will be driven primarily by economic growth (following historical trends) and continued low world energy prices. Once the rapid introduction of gas into the power market slows, emission projections rise. It is implicitly assumed that policy to reduce energy intensity and promote decarbonisation will not change. Furthermore, the saturation of demand for energy-intensive activities typical of advanced economies may not be fully incorporated. Projections based on these types of assumptions have historically proved too high.

As the analysis of the recent past shows, both the adoption of available energy technologies and prices to energy users may be influenced by policy. Projections based on scenarios in which environmental policies are included show a different trend of continuing emissions reductions. For example, the emissions in the European Commission's "Forum" scenario are also shown in Figure 9 (CEC, 1996). This projection assumes policies and measures to assist energy efficiency and renewable energy sources. In this case, emissions continue to fall, broadly in line with the UK Government's target.

FIGURE 9: Projections for UK Carbon Emissions, 1990-2010



Source: Scenario as described in Energy Paper 65 (UKDTI, 1995).

Energy and emissions projections therefore depend on policy assumptions. In the UK at least, substantial reductions in emissions are possible, but will not be achieved without further action. A number of detailed, independent analyses of the UK situation have indicated that policy changes will be needed in all of the major energy-using sectors if the UK Government's 20% reduction target is to be achieved. However, such a target can be achieved without any economic difficulties, because of the substantial scope for "no regrets" measures, notably energy efficiency, new renewable energy sources, and more sustainable transport systems (see, for example, Eyre, 1997; Smith and Marsh, 1997; ESD, 1998). The barriers to these measures are largely social and institutional rather than economic.

However, the CO_2 target cannot be viewed in isolation. Fossil fuel use is so integral to the UK that other factors will have to be taken into account. Some policies that would reduce emissions might cause other economic, social, or political problems; in other cases, potential benefits other than CO_2 emissions reduction should be taken into consideration. In particular:

- In the industrial sector, policies should seek to encourage sustainable technologies for export to strengthen the UK economy and increase employment, but avoid changes that damage international competitiveness or produce large shocks in already weakened industrial sectors.
- In the household sector, policies should seek to alleviate fuel poverty and associated health effects, not exacerbate them.
- In the transport sector, emissions reduction policies should also aim to reduce traffic congestion and urban air pollution, while keeping mobility affordable.

Power Generation

The Government has recently completed a review of policies affecting fuels for power generation. This was triggered by concerns that the large power-generating companies planned not to renew contracts for UK deep-mined coal, an industry that has already suffered big job losses in regions of high unemployment. The review has concluded that the "dash for gas" was affected by imperfections in the market, in particular the market power of the major generating companies and the complex system of settlement for imbalances between power bids into the market and actual generation. It is proposed that new CCGT will not be authorised until the market structure is changed. This is likely to slow, but not stop, the decline in use of coal. The review has recognised the environmental benefits of CHP and renewables.

A review of renewable energy policy is also being undertaken, with a view to outlining policies to achieve the government's target of 10% of electricity from renewables by 2010. It seems likely that the target will be confirmed and that the NFFO mechanism will be continued, perhaps with some modifications. It is also expected that future orders will seek to develop offshore wind resources and energy crops (short-rotation coppice willow and poplar).

The previous government's target of 5000 megawatts (MW) of CHP capacity by 2000 will be achieved or approached. With the CCGT moratorium, the prospects for CHP are good, and the Government is expected to set a target of 10,000 MW or higher for 2010.

Electricity market liberalisation is likely to encourage the development of an unsubsidised "green electricity" market among environmentally concerned consumers. At present, the size of this niche market is unknown, but demand could well exceed supply. One key concern is the need for an accreditation process: currently, there is no agreement among industry, government, and NGOs on how this should be achieved.

The continued expansion of gas, CHP, and renewables (with only a slow decline in nuclear generation) at the expense of coal and oil can be expected to bring further substantial reductions in power sector emissions.

Manufacturing and Services

It seems likely that there will be more negotiated agreements between industrial sectors and government. There is sufficient information available about best practise and likely rates of technological development (based on the Energy Efficiency Best Practise Programme) to conclude agreements that are consistent with continuing declines in industrial energy intensity without damaging competitiveness. However, negotiated agreements are unlikely to be sufficient in this sector for the following reasons:

- Some sectors are too fragmented to conclude effective agreements.
- The voluntary principle is rather weak and inconsistent with the legally binding targets under the Kyoto Protocol.
- In the key energy-intensive sectors, the approach may be overtaken by regulations under the European Directive on Integrated Pollution Prevention and Control (IPPC).

When implemented, the IPPC Directive will, for the first time, place energy efficiency investments on many large industrial sites in the framework of environmental regulation. About half of UK industrial energy use will be covered. This will be an important policy tool, especially if a requirement to use best available techniques is imposed effectively.

The UK Government has recently consulted businesses and other interested parties on the introduction of economic instruments for controlling energy use. A business energy tax is a possibility, especially as it is clear that more progressive business leaders in the UK (as elsewhere in Europe) now recognise that additional policy instruments are necessary if the goals set at Kyoto are to be achieved (e.g., ACBE, 1998). The government is unlikely to impose an energy tax without recycling to business the revenues received. This could be accomplished by a reduction in taxes on labour, by incentives for investment, by financial assistance for emissions reduction or, most likely, by some combination of these measures.

Energy taxation at a national level, even with revenue recycling, is potentially problematic for industrial sectors that are energy intensive and produce internationally traded goods. It is possible that such sectors will be wholly or partly excluded from any tax framework (as has happened in other European countries that tax energy or carbon). A possible alternative is the introduction of an emissions trading scheme for these sectors. This has various attractions:

- It would be possible to link to any similar systems set up in other EU or Annex I countries.
- It is potentially compatible with flexibility mechanisms included in the Kyoto agreement.
- It provides the same incentive as a tax without a large increase in business costs.

On the other hand, it may be difficult to make emissions trading compatible with IPPC regulation. The initial allocation of permits would also be problematic.

Households

In the household sector, there is no realistic possibility of a UK tax in the near future, because of political concerns over “fuel poverty.” However, energy taxation cannot be ruled out as an instrument in the medium term. The European Commission has produced proposals for a draft directive on energy tax harmonisation in the EU, and this would extend taxation to all fuels. Although the directive is unlikely to be adopted in its current form, developments in this direction in the longer term cannot be excluded.

A more likely policy option in the UK is the use of a levy directly on energy supply to fund energy efficiency programmes. The existing Standards of Performance schemes in electricity supply essentially operate on this basis, as the utilities are allowed to pass the costs of schemes through in the unit charge. In a fully liberalised market, this mechanism is not possible, as prices will not be regulated. However, some variants of the approach are viable, possibly with the money raised by a small charge on the monopoly “pipes” and “wires” businesses.

Legislation currently under consideration in the UK Parliament would require mortgage lenders to provide energy efficiency information to householders at the point of sale. This approach could be developed so that lenders include in any loan for house purchase a requirement that the building be brought up to a specified level of efficiency. This approach would bring additional investment from the finance sector, with repayments made over a long period.

The UK Government is giving increased priority to social exclusion and unemployment. Various programmes of this kind may address housing energy efficiency as part of wider concerns. Relevant programmes include the “Environmental Task Force” for young unemployed people and the “New Deal for Communities” to assist the poorest urban neighbourhoods. In addition, the government recently indicated that it will allocate an additional US$6 billion of capital for housing, some of which could be used for energy efficiency. A major increase for the funding of insulation programmes to combat fuel poverty has been announced as well.

Transport

The UK Government’s recently published major review of transport policy includes the following proposals to constrain car use and emissions:

- further differentiation of fuel taxes by fuel type
- vehicle taxes differentiated by engine capacity
- road pricing, particularly related to congestion in urban areas
- taxes on business parking
- increased financial support for public transport
- measures to encourage walking and cycling for short journeys
- re-regulation of bus and train operations to provide an integrated service
- public/private partnerships for infrastructure investment.

Because of the operation of the single European market, movement towards increased vehicle efficiency needs to be taken at the European Union level. The European Commission has negotiated an agreement with European car manufacturers to reduce the average CO_2 emissions from new vehicles to 140 g/km by 2008. The aim is to move towards an average of 120 g/km of CO_2 (equivalent to a fuel efficiency of 0.05 litre/km with gasoline fuel), which would be a 30% improvement on current UK levels. If the agreement proves ineffective, the EU may move towards mandatory standards.

CONCLUSIONS

The UK experience shows that, under some circumstances, emissions from a developed economy will tend to stabilise and fall without strong policies explicitly addressing climate change. In the UK, emissions stabilisation has been achieved by a combination of "business-as-usual trends" and the side effects of other policy initiatives.

The link between energy use and emissions has been broken successively in the industrial, household, and service sectors of the economy, but not yet in transport. The carbon intensity of fuels, particularly electricity, has been reduced. The factors underlying this have been:

- a shift in the balance of economic activity from industry to services
- a shift from energy-intensive to less intensive industrial production
- technical change leading to energy efficiency improvements even with falling energy prices
- population stability
- major efficiency improvements in household heating techniques
- saturation in the uptake of most main household appliances
- the economic strength of high-added-value, low-energy-intensive services.

Some policies adopted for reasons other than greenhouse gas abatement have had positive effects. These include:

- the restructuring of the electricity industry
- the encouragement of technological diversity in power generation
- support for information programmes to reduce energy imports and industrial energy costs
- the development of an extensive natural gas infrastructure
- programmes to address "fuel poverty" by household insulation
- constraints on the use of dirty fuels in urban areas to improve air quality.

Future policies are likely to be more explicitly driven by greenhouse gas reduction concerns. Key policies under active consideration include:

- financial and regulatory support for renewable energy sources and CHP
- taxation of business energy use (or other economic instruments)
- domestic energy efficiency programmes funded by general taxation and/or regulatory measures in the housing finance and energy sectors
- greater use of energy efficiency regulation for buildings, appliances, and vehicles
- use of a variety of economic instruments in the transport sector
- the development of a strong, integrated public transport infrastructure.

Policies of this type have not yet been incorporated into official UK energy projections. If and when they are, it is likely that projected emissions will continue to fall, although the extent and rate of decline are uncertain.

Both projection methodologies and future policies have large inherent uncertainties. It is therefore very unlikely that a national future baseline can ever be established that will receive general agreement (even for a country like the UK, where current energy and emissions data are reasonably accurate). Establishing a baseline methodology suitable for use in diverse countries will be even more problematic. In the context of the CDM, where potentially large resource transfers depend on baseline assumptions, there would be severe pressures on negotiators to adopt unrealistically high baselines. The prospects for agreement on a methodology that avoids the creation of "hot air" therefore seems remote. A project baseline methodology may well be both easier to agree to and more transparent to implement.

The UK analysis, like that for any other developed country, is obviously of limited direct value for setting a project baseline for CDM activities. There is no assessment of the technology needs of developing countries, and development patterns are likely to be very different. However, the analysis may still be useful in the formation of guidelines for the CDM. It can help identify commercially available clean technologies that are already being used in Annex I countries, and therefore available for technology transfer. These include renewable energy technologies, CHP, high-efficiency CCGT, efficient boilers, high-efficiency motors, motor controls, compact fluorescent lights, efficient appliances, and public transport infrastructure. Using these technologies would allow developing countries to follow development paths with significantly lower carbon intensity trends than those followed historically by the developed countries. This is the idea of technological "leapfrogging."

The analysis of the UK also shows the importance of treating baselines as dynamic. Energy intensity in various sectors is a function of development, as can be seen, for instance, in the well-known trend to "saturation" of energy demand and declining carbon intensity as economies develop. On the basis of this analysis, however, the trend is sector specific. For each country the "natural" trend will depend on the economic structure as well as the policies followed to encourage energy efficiency and decarbonisation. But it is likely that in most cases, the baseline intensity in each sector will fall as development proceeds and new technologies become available. There are, therefore, good reasons periodically to revisit assumptions about baselines to ensure that they do not become fossilised.

REFERENCES

ACBE, 1998: Advisory Committee on Business and the Environment. Climate Change: A Strategic Issue for Business. ACBE Secretariat, DETR.

CEC, 1996: Commission of the European Communities. Energy in Europe — European Energy to 2020.

ESD, 1998: Energy for Sustainable Development. Cutting CO_2 — Creating Jobs: An Economic Analysis of Policies to Cut UK CO_2 Emissions by 20% or More. Friends of the Earth, London.

EST, 1998: Energy Saving Trust. June 1998 Update.

Eyre, N.J., 1997: Taking a Cool Look: Policies to Reduce UK Carbon Dioxide Emissions by 20%. Socialist Environment and Resources Association, London.

Mitchell, C., 1998: Renewable Energy in the UK. Council for the Protection of Rural England.

NAEI, 1997: UK National Atmospheric Emissions Inventory. UK Emissions of Air Pollutants, 1970-95. Department of the Environment Transport and the Regions.

Smith, A.C. and Marsh, G.P., 1997: CO_2 Reduction Policy Options: An ETSU Viewpoint. ETSU, Harwell.

UK DOE, 1994: Climate Change — The UK Programme. United Kingdom's Report under the Framework Convention on Climate Change. Cm 2427. HMSO.

UK DOE, 1995: Climate Change — The UK Programme. Progress Report on Carbon Dioxide Emissions. Department of the Environment.

UK DOE, 1997: Climate Change — The UK Programme. United Kingdom's Second Report under the Framework Convention on Climate Change. Cm 3558. The Stationery Office.

UKDTI, 1995: UK Department of Trade and Industry. Energy Projections for the UK. Energy Use and Energy-Related Emissions of Carbon Dioxide in the UK, 1995-2020. Energy Paper 65. HMSO.

UKDTI, 1997a: UK Department of Trade and Industry. Digest of UK Energy Statistics. The Stationery Office.

UKDTI, 1997b: UK Department of Trade and Industry. Energy Consumption in the United Kingdom. Energy Paper 66. The Stationery Office.

UKDTI, 1997c: UK Department of Trade and Industry. The Energy Report — Shaping Change. The Stationery Office.

CHAPTER 7

Investing in carbon storage: a review of Brazilian forest projects

Èneas Salati
Technical Director
Brazilian Foundation for
Sustainable Development
Senior Researcher
CEA / UNESP, Brazil

Weber Amaral
Professor, Department
of Forest Sciences
ESALQ – University
of São Paulo, Brazil

Angelo Augusto
dos Santos
Senior Researcher
Brazilian Foundation for
Sustainable Development

SUMMARY: This paper analyses Brazil's current initiatives and alternatives to decrease deforestation and increase carbon storage. The analyses are based on forest-related projects, including the expansion of the Brazilian plantation area, implementation of agroforestry projects in degraded areas of the Amazon Basin, rehabilitation of native forests, sustainable forest management projects, and restoration of gallery forests along the banks of rivers and streams. Estimates are provided for each of these initiatives on project-specific baselines, on costs per ton of carbon sequestered, and on the potential costs of investments for carbon sink projects.

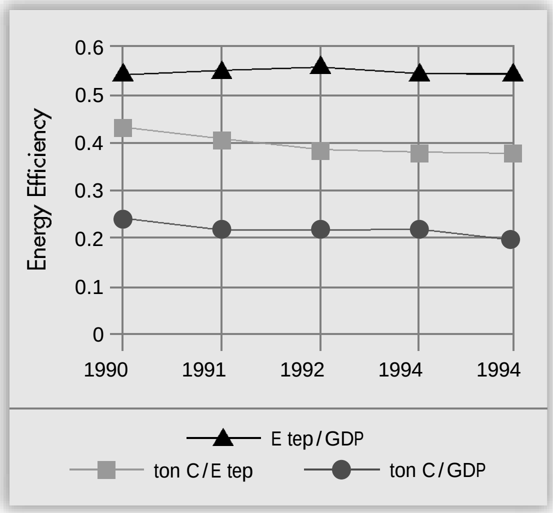
INTRODUCTION

Because of its size, the extent of its forests, and its rate of industrialisation, Brazil is a key player in the climate change arena. Many Brazilian policies and initiatives of the last few decades have resulted in real reductions of carbon emissions, as detailed in the next section, even though that was not their primary purpose. Moreover, Brazil has made a substantial commitment to renewable sources of energy, such as hydropower and biomass. Renewable resources represent at least 55% of Brazil's energy production (Rosa and Schechtman, 1998). In addition, energy efficiency has been improving during the last few years, as shown in Figure 1.

According to Rosa and Schechtman, energy intensity (E/GDP), as shown in the top line of Figure 1, remained relatively constant from 1990 until 1994. However, the ratio between tons of carbon emissions and GDP (also referred to as the carbon intensity of the economy) from the same period shows that Brazil is using less fossil fuel to produce the same GDP. In addition, because Brazil's energy matrix is heavily concentrated in hydropower production, Brazil's economy has even lower carbon intensity than countries like China and India (See Goldemberg and Reid in this volume).

A particularly promising area for further reduction of GHGs — especially carbon emissions — is in the land use and forestry sector, which in Brazil has been the focus of several public policies

FIGURE 1: Brazil's Energy Efficiency, 1990-1994



Source: Rosa and Schechtman, 1998.

Note: Energy efficiency in this chart is measured by the ratios of carbon emissions to GDP, tons of carbon emissions to total energy production (tep), and energy production to GDP.

designed to reduce deforestation rates. Furthermore, many multiple-use forest projects may improve atmospheric CO_2 levels through a net sequestration of carbon.

According to the Intergovernmental Panel on Climate Change (IPCC, 1995), tropical America has the highest worldwide potential for carbon conservation and sequestration — amounting to between 21 and 33 gigatons of carbon. Whether this potential is realised, however, depends on the availability of land for multiple-use tree planting and farming projects and the rates of deforestation.

In the debate about the role forests play in the global climate balance, they have been characterised as both villain and hero, as both a source of carbon emissions and a sink for carbon storage. Many scientists consider boreal and temperate forests as carbon sinks (Dixon et al., 1994), while tropical forests are treated as carbon sources because of deforestation and burning (Fearnside, 1997). However, most of the world CO_2 emission inventories do not take into account the potential for carbon sequestration through the secondary regeneration of tropical forests, whose annual growth rate varies from 7 to 30 cubic meters per hectare. Therefore, good estimates are still missing. In this chapter, the forest's role in carbon storage is emphasised and its role as a source of carbon is shown to be a result of unsuitable public policies and changes in land use.

We argue that agroforestry activities, rehabilitation of degraded forests, and multiple-use plantations, besides increasing carbon storage, lessen the pressure on primary forests and, indirectly, help reduce the amount of land clear-cut every year. Moreover, these activities do not compete with farming and must be considered, along with sustainable forest management practices, as viable ways to increase productivity in agroforestry systems and to integrate subsistence farming practices into economically and ecologically sustainable models.

The management of tropical forest regeneration offers a simple and relatively inexpensive possibility for carbon sequestration, one more easily accepted by local populations than large-scale plantations (Grainger, 1990; Nilson and Schopfhauser, 1995). However, forest restoration programmes that combine multiple-use forests and agriculture should also be considered. These practises can relieve pressure on areas with primary forests, thereby conserving the biodiversity found within them (Lugo et al., 1993; Parrota, 1993).

With its vast size (8.45 million sq km) and extensive coverage by tropical forests and multiple-use plantations (Table 1), Brazil plays a major role in the global CO_2 balance. Brazil can, therefore, contribute significantly to the mitigation of greenhouse effects through reducing carbon

TABLE 1: Area of Native Forests in Brazil (1000 ha), Excluding Plantations

Region	Total area covered with native forests	Area covered with primary forests
North	300,000	253,000
Northeast	77,000	29,000
West central	127,000	74,000
Southeast	37,000	15,000
South	5000	3000
Total	**546,000**	**374,000**

Source: Adapted from FAO, 1997.

emissions, increasing carbon uptake, and finding ways to reduce deforestation. This preliminary study is based on the literature available about Brazil's potential to mitigate greenhouse effects through forest-based carbon sink projects. We estimate project-specific baselines and costs for each type of project. Some of these programmes are already underway, and the Clean Development Mechanism (CDM) could provide additional funding to make them more cost-effective. Other pioneer initiatives are also presented, although their estimated costs are still unclear.

MITIGATION PROJECTS AND INITIATIVES ALREADY IMPLEMENTED

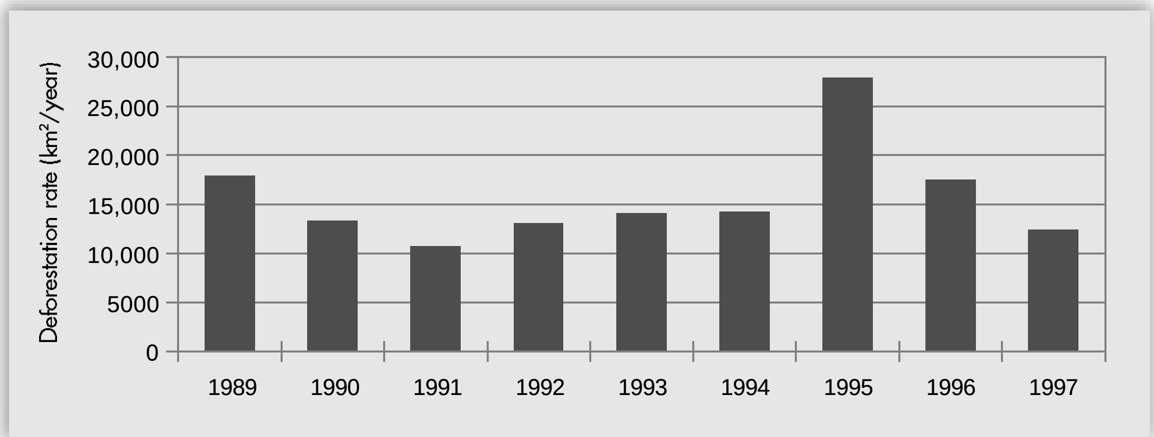
In addition to several projects already implemented in the energy sector — including, for example, the alcohol fuel program, which has generated more than 700,000 jobs and reduced urban pollution (Reid & Goldemberg, 1997) — Brazil has adopted several forest policies designed to decrease deforestation rates.

Data from the National Space Research Institute (INPE) show that deforestation rates in the Brazilian Amazon have dropped since 1995 (Figure 2). The latest survey shows that the cumulative deforested area is around 517,069 sq km — approximately 12.9% of the original Amazon forest cover. From 1978 to 1998, the average annual deforestation was around 2 million hectares, resulting in CO_2 emissions of about 300 million/t/y or 6 billion/t/C (CO_2) in twenty years. However, these numbers do not take into account forest regeneration, for which there are no data available. Brazil is currently preparing its country inventory of GHGs that will help to quantify this.

Although deforestation is still taking place, numerous activities are being conducted in the region to slow it down. Extraction of non-timber forest products, such as rubber, Brazil nuts, essential oils, and medicinal products — along with sustainable forest management practises — is being carried out in extractive and indigenous reserves and by private companies.

The large-scale deforestation in the Brazilian Amazon has numerous causes that are difficult to analyse and generalise about. Thus, in this chapter we do not address these causes directly. However, we offer a number of alternatives that are likely to relieve pressure on the remaining forests and increase carbon storage overall. Increased productivity in agroforestry systems in the Amazon Basin could help farmers make the transition from current slash-and-burn practices to more sustainable models, thereby minimising land use changes at the landscape level. Some projects of this scope are already being adopted: EMBRAPA (Brazilian Company for Agricultural Research), for example,

FIGURE 2: Deforestation Rate in the Brazilian Amazon, 1989-1997



Source: INPE, 1998.

provides technical assistance to small farmers implementing agroforestry systems in the Tomé-Açu region of southern Pará. Non-government organisations in the Amazon play an important role as well. The Instituto do Homem e Meio Ambiente da Amazônia (IMAZON, the Amazon Environmental and Human Institute) has been generating information on the ecological and economic feasibility of agroforestry systems and sustainable forest management practices. IMAZON also makes this information available to farmers and forest-oriented business companies in the region.

Federal and state legislation in Brazil requires that states keep a certain percentage of land as forest: 50% for the northern states and 20% for the southern states. In certain areas, particularly in the southern states, where these requirements are not yet being met, the landowners will have until the year 2005 to comply. Since 1990, more than 12,000 ha of afforestation projects have been implemented in the southern states alone.

In addition, in the southeastern Brazilian states of São Paulo and Minas Gerais, forest replanting funds from timber taxes have been used to plant more than 10 million trees, or the equivalent of 6000 ha in small-scale reforestation projects, ranging from 1 to 25 ha. Not only have these projects increased forest cover and timber production, but they have also diminished the pressures on the last remnants of the Atlantic rainforest. Although these programmes are limited in scope, considering the size of the country, they could be extended if additional resources were available.

Brazilian legislation also requires the conservation of gallery forests and riparian corridors along banks of rivers, lakes, and reservoirs. The size of these corridors varies according to the width of rivers, lakes, and reservoirs. In many regions of Brazil, especially in the states of Minas Gerais, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul, government and non-government programs distribute seedlings of native tree species to restore the original gallery forest. Although precise figures for the area already restored by these programs are not available, the most pessimistic estimate for the state of Santa Catarina alone indicates that an area of 6000 ha was planted along riparian corridors.

Charcoal production programs, based on afforestation projects in the states of Minas Gerais, Mato Grosso, Mato Grosso do Sul, Maranhão, and Pará for the Carajás project, have been carried out since 1980. The first programme, designed by the State Forestry Institute of Minas Gerais (IEF), has been very successful in supplying charcoal to pig iron plants in Minas Gerais, thereby avoiding the use of native trees and decreasing the deforestation rate of the savanna-like Cerrado ecosystem. About 1 million ha of afforestation projects were established to supply wood for charcoal production in Minas Gerais.

POSSIBILITIES FOR CARBON SEQUESTRATION: THE AMAZON REGION

The Brazilian Legal Amazon extends across 5 million sq km (500 million ha), of which 3.7 million sq km (74% of the total area) is covered with tropical rainforests. Besides the extraordinary bio-diversity of the Brazilian Amazon (Wilson, 1988), its CO_2 stock is approximately 60 billion tons of carbon (excluding the deforested areas), which equals 37% of all carbon stored in tropical forests world-wide (Fearnside, 1998). The conservation of carbon stocks — an important environmental service provided by countries with large areas covered by forests — is inexpensive compared to CO_2-mitigating alternatives (Table 2). As Seppala and Siekkinen (1993a) have calculated, a ton of carbon kept in forest stocks would be worth US$5 per ton. Although maintaining carbon stocks was not considered a mitigating alternative in the Kyoto Protocol, Norway, Sweden, and Finland are already considering the added value of their

TABLE 2: Area and Carbon Stocks from Native Forests and Plantations in Brazil up to1996

Stocks by forest types	Native forests	Plantations
Forest area (x 1,000 ha)	546,000	6000
Carbon stock (billion ton C)	116.4	1.0

forests as carbon stocks for mitigation purposes (Seppala and Siekkinen, 1993b). In Finland particularly, the forestry sector is considering providing subsidies to forest owners to preserve their forests — or, at least, to use the timber to manufacture forest products of long life cycles (over 25 years).

In the Amazon area, the creation of buffer zones that combine agriculture with forestry activities in the degraded areas along the cattle-ranching frontier could provide an alternative to clear-cut practises. These zones, established in degraded pastures, could also served as a network of observation sites, to gather data on agroforestry activities and carbon sequestration rates, and to monitor deforestation. Cost-benefit analyses of these activities should be carried out and compared with the economic feasibility of extensive cattle-ranching practices and other land uses. These buffer zones would be planted with multiple species in longer rotation cycles and distributed in edaphically distinct regions to provide information on the efficiency of carbon uptake through agroforestry activities and sustainable models of land use. These projects could then serve as control groups to estimate carbon uptake; the data generated will be used to check the already defined baselines and diminished the pressure in non-degraded areas.

Approximately 40 million ha of degraded areas in the Amazon (Salati & Santos, 1998) should be prioritised as buffer zones. These areas could also be used by the Brazilian Government as part of the current agrarian reform program. Nevertheless, rural settlement projects must be carefully studied and monitored by skilled agroforestry staff, who understand the economic exigencies and social dynamics of such settlements. We estimate that the carbon uptake of these areas could reach more than 200 million tons of carbon per year (C/year), at an annual fixation rate of 5 tons of carbon per hectare per year (C/ha/year). The recommended mix of tree species would be from different successional stages — pioneer, secondary, and late successional species — so they would have different harvesting times.

POSSIBILITIES FOR CARBON SEQUESTRATION: THE FLORAM PROJECT

In Brazil, a large-scale forest restoration project called the Floram Project (Floram: *flor,* "forests," and *am,* "environment" in Portuguese) was conceived in the early 1990s. One of the most carefully thought-out forest restoration projects in Brazil (Marcovitch, 1990), it remains in the conceptual stage because of a lack of funding. The Floram Project was initially designed by a group of professors from the University of São Paulo, and refined with the help of representatives of the business sector. Its primary aim is to sequester CO_2 in multiple-use forests spanning an area of 20 million ha (2.3% of Brazilian territory) in the Atlantic rainforest area over a period of 20 to 30 years (Barrichelo, 1990). If fully implemented, it would take up an estimated 154 million tons C/year, assuming an average productivity of 7.7 tons (C/ha/year). That would amount to approximately 3.85 billion tons of carbon in a rotation of 25 years.

In addition to rehabilitating degraded areas in different ecological regions of Brazil, the Floram Project classified the restoration projects into three categories:

- functional restoration projects (14.4% of the total area to be reforested)
- plantations (71.8%)
- forests with multiple-use forests and social forestry (13.8%)

The importance of this project for carbon fixation, rehabilitation of degraded areas, and multiple use of forests was acknowledged internationally (Brown and Lugo, 1992), but because of its huge scope, it was difficult to put into operation. Despite its operational complexities, the design of Floram and its premises are still valid and up-to-date. Similar projects are being implemented in other countries (Thailand, Mexico, Panama, Nepal, Peru), but on a much smaller scale and with lower rates of carbon sequestration per hectare (Faeth et al., 1994). In Brazil, even the most pessimistic forecasts for carbon sequestration using fast-growing forests vary between 6.9 and 7.2 tons C/ha/year, with some forest sites having a carbon uptake rate of more than 20 tons C/ha/year.

Floram's multiple-use reforestation proposal, besides addressing carbon storage, provides the maintenance of basic environmental services, such as water production and soil conservation in different ecosystems. It would, for instance, help protect the last remnants of Atlantic rainforest areas, whose conservation has attracted world-wide attention (Lino, 1992), including designation as a Biosphere Reserve Area by UNESCO. Although only 9% of its original cover remains (Lino, 1992), the Atlantic rainforest has a highly diverse representation of primate and tree species (Amaral, 1994), and many native species that are found nowhere else. However, the feasibility of this project depends on international financial support, which could come from the CDM.

Multiple-use forest restoration projects such as the Floram Project require considerable capital. CDM funds invested in such multiple-use reforestation and restoration projects, with monitoring by appropriate Brazilian NGOs and United Nations agencies, could offer a decisive contribution to their implementation.

Such projects also deserve special technical attention, which is not currently a limitation in Brazil. Nurseries and forestry cooperatives could centralise the production and distribution of seedlings. Besides supplying seedlings, these cooperatives would provide forestry courses and technical assistance to farmers and peasants in forestry techniques, as well as help them organise small agribusiness enterprises and market their products. Cooperatives would be distributed in ecological regions where severe deforestation has occurred, and in regions where pressure on natural forests is high. Floram has already zoned these areas, but an update is required.

POSSIBILITIES FOR CARBON SEQUESTRATION: PLANTATIONS AND MULTIPLE-USE FORESTS

Fast-growing plantations for industrial purposes in Brazil cover approximately 5.5 million ha, and represent a dynamic stock of carbon of about 1 billion tons. Approximately 60% of the country's plantation area is covered with Eucalyptus species and 34% with Pinus species (Marcolin, 1998). The incremental increase of carbon stock in fast-growing forests planted in Brazil between 1990 and 1994 was estimated to be about 108.8 million tons C/year.

The dynamics of carbon sequestration by plantations depend on the end-use of wood material. For instance, carbon stored in wood produced for pulp and paper has a short life cycle (less than five years). But in other forest products, such as timber, fiberboard, and wood panels, the carbon may be stored for over 50 years (Seppala and Siekkinen, 1993a). Plantation activities in Brazil are based in afforestation projects only. Their impact on carbon storage differs drastically from forestry activities in developed countries in which native forests are managed for wood production, resulting in a net release of carbon, which was initially stored in the biomass.

Plantations in Brazil uptake carbon from the atmosphere, and should therefore be considered as a dynamic stock of carbon. The primary dynamic stock corresponds to the total area planted with forests minus the annual consumption of wood (that is, wood actually harvested by the forestry industries). The secondary dynamic stock of carbon depends on the final use of the wood that is harvested. This stock could be only a few days for paper products or a 100 years or more for a piece of solid wood furniture, for example.

Considering the growing demand for more durable forest products (solid and non-solid products) and the new techniques for their large-scale production at competitive prices, Brazil could gain a larger share of the world market for these products. Brazilian exports of forest-based products have almost tripled during the past six years. Exports of plywood, a long-life-cycle product, grew to US$1.1 billion in 1996, and the annual growth forecast of Brazilian exports of solid timber products is more than 6% (Macedo et al., 1997).

Owing to ecological factors, the availability of well-developed silviculture technology, including tree-cloning techniques, and low planting costs, the planted forests in Brazil are more competitive than those in the temperate countries in terms of productivity, rates of carbon uptake and costs for sequestering carbon (Table 3). Yet the major

Brazilian contribution to carbon sink by the commercial forests must occur mainly when the raw timber is used in long-life-cycle products — for instance, fibreboard, timber, plywood, and new manufactured lumber products, such as engineered lumber products and panels, like MDF (medium density fibreboard) and OSB (oriented strand board), which have a working life of more than 50 years.

Planted forests can also generate biomass for energy generation by direct combustion, charcoal production, or gasification. In 1993, the annual fuel wood consumption in Brazil was estimated to be approximately 25.4 million tons oil equivalent (Mtoe). (One ton of dry timber corresponds to 0.44 ton of equivalent oil.) However, consumption forecasts for the years 2000 and 2010 are 36.7 and 46.7 Mtoe, respectively (Brito, 1997), indicating that the fuel wood demand will rise by approximately 22% in the first 10 years of the next century. Despite the increase in the use of other energy sources, Brazil will continue to be very dependent on the use of fuel wood by direct combustion — which is not very efficient in energy conversion, particularly in the rural areas. On the other hand, gasification, a process in which wood shavings are crushed and turned into gas at a high temperature, converts forest biomass into energy at an efficiency level at least five times higher than that achieved by simply burning timber (Stassen, 1995). Planting to increase the supply of wood for fuel and gasification, especially in the northeast of Brazil, offers a renewable source of energy, can release pressure on the native vegetation, and can reduce the dependence on fossil fuel derived products.

TABLE 3: Average Productivity and Cost of Carbon Uptake by Different Countries for Coniferous and Broad-Leaf Forests

a. Average productivity of coniferous forests and C uptake

Country	Productivity (m^3/ha/year)	Carbon uptake (tons C/ha/year*)
Sweden	3.5	0.8
Canada	2.5	0.6
USA (Southeast)	10.0	2.5
Chile	22.0	5.4
New Zealand	22.0	5.4
Brazil	28.5	7.0

b. Average productivity of broad-leaf plantations and C uptake

Country	Productivity (m^3/ha/year)	Carbon uptake (tons C/ha/year*)
Sweden	5.5	1.35
USA (Southeast)	15.0	3.5
Portugal	12.0	2.94
South Africa	18.0	4.43
Brazil	37.0	9.2

* Aboveground biomass only

Source: FBDS, 1994.

Productivity (m^3/ha/year): trunk volume that is the commercial volume of the timber, which is equal to 70% of the total tree biomass (30% correspondence to bough, branches, stumps, and roots).

INVESTMENT POTENTIAL FOR IMPLEMENTING CARBON SINK PROJECTS IN BRAZIL

The area available in Brazil for forestry projects to mitigate greenhouse effects is considerable — approximately 60 million ha (Ab'Saber, 1990; Salati and Santos, 1998). With appropriate management, this area could sequester between 5 and 10 tons C/ha/year, for a total sequestration of 450 million tons C/year and 9 billion tons over a 20-year period. At least 30% of these areas — riparian corridors, steep slopes, and areas at high risk of soil erosion — will not require any sort of intervention. These areas could sequester some 3 billion tons, whereas the other 70% — areas requiring low to moderate management — constitute an additional dynamic stock of carbon of around 6 billion tons.

On the basis of the Floram project assumptions (Table 4), the costs of carbon uptake of these mitigation projects range from US$4.50 per ton of carbon sequestered for plantation projects

TABLE 4: Estimates of Carbon Uptake, Project Rotation, Costs per Ton of Carbon Sequestered, and Carbon Life Span from Three Categories of Forest-Based Mitigation Projects

Mitigation alternatives	Carbon uptake (ton C/ha)	Rotation (years)	Total ton C (uptake/rotation)	Cost ton C (uptake/ha)	C life span (years)
Plantation*	10-14	10	100-140	2-5	2-50
Agroforestry**	6-9	40	240-360	4-8	5-100
Restoration***	8-12	Over 100	800-1200	5-9	Over 100

Carbon uptake, estimated from above- and below-ground stocks, in tons C/ha.

Sources: * Bracelpa, 1998; ** IMAZON, 1997; *** CESP, 1996.

(BRACELPA, 1998) to US$8.00 for forest restoration and social forestry. Mitigation projects in the Amazon region might fall on the high end of this range (US$8.00 per ton) and require longer rotations.

The overall funding to implement these mitigation projects at a rate of 3 million ha/year amounts to US$2.82 billion, or about US$56.4 billion over a 20-year period. We define these projects as the investment potential of Brazil to develop and implement forest-based mitigation projects. They represent the lowest opportunity costs of the market — in other words, a lower cost of ton of carbon sequestered per hectare than any other forest projects so far presented (Faeth et al., 1994; IPCC, 1995).

We realise that the cost of implementing mitigation projects for 60 million ha of forests is a large amount to be raised just through selling Certified Emission Reductions (CERs); therefore, in the next sections we present some the scenarios for investment opportunities, and their baselines.

INVESTMENT OPPORTUNITIES FOR FOREST-BASED CDM PROJECTS

This section offers possible initiatives, defined as investment opportunity scenarios for forest-based projects. These are analysed over a broad economic perspective, beyond micro- or macroeconomic indicators, taking into consideration carbon uptake, income generation, and the provision of environmental services (water production, control of soil erosion, and biodiversity conservation). Because of this wide range of benefits, in terms of both carbon uptake and sustainable development, such projects amply fulfil the objectives set for the CDM in the Kyoto Protocol.

Implementation Costs of Carbon Sink Plantation-Based Projects

The National Association of Pulp and Paper Manufacturers of Brazil, which has 37 of the largest Brazilian reforestation companies as members, provides the most reliable statistics on the forestry sector in Brazil. During the past 20 years, the organised forestry sector planted more than 1.5 million ha of pine and eucalyptus forests, with high productivity for industrial purposes (paper, lumber, plywood, fibres, etc.).

Plantations (afforestation projects) sequester between 10 and 14 tons C/ha/year (Table 4), with a cost per ton of carbon sequester ranging from US$2 to US$5 per ton C per ha, not considering land prices. A CDM program in Brazil could be designed to double the annual planted area with fast-growing species to 100,000 ha, which would sequester 1.4 million tons C/year, with a cost of US$90 million per year (Table 5).

Implementation Costs for Agroforestry Projects

During the past 40 years, the population in the Amazon region has soared. Between 1960 and 1991 alone, it increased by 14 million inhabitants, with a total growth rate of 700%, much of this due to migration. Growing populations have placed ongoing pressure on the ecosystem. One of the main causes of deforestation is the clearing of new areas of forest by migrant farmers. After clearing, the soil is cultivated for two or three years and then abandoned, as the settler moves on to new, untouched forest areas.

The implementation of agroforestry systems could help this situation. Agroforestry techniques that are already reasonably well developed (for example, the EMBRAPA-Tomé-Açu project) could help the rehabilitation of degraded areas, so that settlers could live in a sustainable way, rather than moving on to clear additional natural forests. Estimates show that between 30 and 40 million ha in the Amazon are suitable for agroforestry projects for both small and large farms. As required by the Brazilian environmental legislation for the Amazon Basin, each farm should have 50% of its area covered with native species, whereas the other 50% could be used in agroforestry projects.

In this chapter, we do not provide a detailed appraisal of demand and operating costs for these kinds of projects. However, we estimate that to implement an area of 50,000 ha/year, a feasible project scale initially would require an investment of US$75 million a year, and result in carbon uptake of 300,000 tons per year (Table 5).

Implementation Costs of Carbon Sink Sustainable Forest Management Projects

A real possibility of maintaining carbon stocks in the Amazon forest is to require sustainable forest management (SFM) practises in all logging areas. Several experiments are in progress, some of them undertaken by the Precious Wood and Madeireira Mil companies, which produce timber in a sustainable way and have been awarded international certificates. Sustainably managed forests generally have rotation cycles of 25 to 30 years. Between 25 and 30 cu m of timber per hectare is removed, with additional removals from the same site only after 25 years. The cost-benefit studies carried out by IMAZON have not yet determined whether SFM of tropical forests in the Amazon is an option. The area currently under SFM is around 300,000 ha, with an average carbon sequestration of about 150 tons/ha. In the forests that could be managed in a sustainable manner, the carbon storage would amount to 50 billion tons.

SFM practices have not yet been shown to be economically feasible, but they do result in low rates of carbon being released into the atmosphere (29-68 tons/ha). Additional funding from the CDM to pay for carbon stocks after logging operations, however, could make SFM profitable, and stimulate its widespread adoption in the Amazon region. Additional funding should be calculated on an individual project basis; therefore, we do not provide these calculations here.

Implementation Costs of Floram Projects

In the Brazilian Atlantic rainforest areas considered by the Floram project, the demand for wood fibre is high and diversified. Forest products are used for pulp, paper, fuel wood, charcoal, wood panels, furniture, household uses, packing, and containers, as well as for construction. This region

TABLE 5: Projected Investment Opportunities in Certified Emissions Reductions from CDM Projects in Brazil

Mitigation alternatives	Cost/ha (in US$)	Area (ha/year)	Ton (C/ha/year)	Rotation (years)	Ton C (uptake/year)	Cost/year (in US$)
Floram	2100	15,000	9	20-40	135,000	31.5 million
Riparian corridors	1700	10,000	12	Over 100	120,000	17 million
Buffer zones/AgriFo	1500	50,000	6	40	300,000	75 million
Plantations	900	100,000	14	10	1,400,000	90 million

also has the largest concentration of the Brazilian population (around 63%), along with good infrastructure and transport systems, and is therefore suitable for plantation projects as well as social forestry (publicly owned forest areas used for multiple purposes) and restoration projects. A tentative program to establish 15,000 ha of forest per year, with an uptake of 135,000 tons of carbon per year, has an estimated cost of US$31.5 million per year (Table 5).

Implementation Costs of Riparian Corridor Projects

The potential for restoration of riparian corridors throughout Brazil is enormous. The São Paulo State Energy Company (CESP) alone has an area equivalent of 70,000 ha of degraded areas along rivers and reservoirs that were used for energy generation. CESP currently has the most updated forestry techniques to restore these areas; however, these could also be used to restore privately owned riparian corridors, which are not covered by the CESP program. Initiatives such as the CDM could improve such restoration strategies, increasing the biodiversity by using many more tree species, and by matching other, already available funds. The municipalities and energy generation companies are already contributing by the production and distribution of seedlings. However, additional funds from the CDM could also be used by small private reforestation companies or small landowners to restore selected areas — mainly watershed basins and human consumption reservoirs. This program could be administered through the municipalities and could restore 10,000 ha of forest per year, for a cost of US$17 million per year and a potential uptake of 120,000 tons of carbon per year (Table 5).

BASELINES OF FOREST PROJECTS

Mitigation initiatives that will be eligible for CERs through CDM projects will have to meet certain criteria set forth in the Kyoto Protocol (see Article 12.5 of the Protocol), including additionality above agreed-upon baselines. Additionality implies reductions in emissions that are supplementary or extra to any that would occur in the absence of the certified project activity. Because the forest-based projects presented in this chapter are mostly new initiatives, they are clearly additional to current programs. Thus, we argue that these projects might be eligible for CER, once baselines are properly defined. This is one of the reasons why defining emission baselines is so critical.

Calculations of the reductions of carbon emissions or carbon sequestration rates of projects eligible for CERs through the CDM depend upon the baseline definitions entirely. In this chapter, we argue that project-specific baselines are preferable to country- or sector-specific baselines because they provide a good depiction of reality (Michaelowa and Dutschke, 1998). However, because they involve prediction of changes in land use, baselines for forest-based projects might be difficult to estimate. Alternatively, a dynamic

TABLE 6: Project-Specific Forest Baselines Assumptions

Assumptions for plantation projects	Assumptions for agroforestry projects	Assumptions for restoration projects	Assumptions for SFM projects
Implementation in degraded areas	Implementation in degraded areas	Implementation in degraded areas	Implementation in native forests
No substitution of native forests by plantations	Cattle ranching will cause carbon emissions	Soil erosion increases	Land use change is expected
Ongoing loss of carbon stocks from the soil	Ongoing loss of carbon stocks from the soil and vegetation	Ongoing loss of carbon stocks from the soil and vegetation	Expected loss of carbon stocks from vegetation and soil

TABLE 7: Comparative Analysis of Different Forest-Based Mitigation Projects

Project	Baseline	Land use	Rotation	Risk levels	Costs
SFM	High	High	High	High	Low
Agroforestry	Low	Intermediate	Intermediate	Intermediate	Intermediate
Restoration	Intermediate	Low	NI	Low	High
Plantation	Low	Low	Low	Intermediate	Low

SFM: Sustainable forest management. **NI:** No intervention. **Baseline:** Possible amount of carbon loss: SFM would have the highest rate of carbon loss, and agroforestry and plantations the lowest rate. **Land use changes:** The likelihood of land use changes; potential areas for SFM would have the highest probability to be converted into pastures or into degraded forests, whereas restoration and plantation areas would have the lowest. **Rotation:** SFM projects would have the longest rotation cycles, whereas plantation would have the shortest. Restoration project would not have any intervention. **Risk levels:** Positively correlated with the rotation of each project and the likelihood of loss due to uncertainties, such as fire, flood, invasions. **Costs:** Opportunity costs, which do not reflect the cost of land. Restoration project would have the highest cost of implementation, whereas plantations would have the lowest.

baseline approach offers a way to avoid problems with inefficiency and spurious claims for emission reductions based on unreliable baselines. This approach requires that baselines be verified periodically, and corrections should be made on the basis of these verifications. A dynamic baseline for forest projects is therefore feasible, because measurements of carbon uptake are easier to make and less expensive than other project-specific baselines, and could overcome the difficulties stated above.

In the case of forest baselines, project-specific assumptions should be agreed upon. Table 6 shows standard assumptions for four types of forest projects: plantations, agroforestry, restoration, and SFM.

Using these assumptions, we can estimate the baselines for each of the categories of projects in terms of total carbon losses. The baseline scenario in the absence of each project implies loss of carbon as a function of current carbon stocks, which therefore should be site-specific. Therefore, our baselines are rough estimates, and accurate baselines need to be determined empirically, case by case.

The baseline for plantation projects varies from 0.5 to 5 tons of C/ha; for sustainable forest management projects, it varies from 120 to 250 tons of C/ha; for restoration projects, it varies from 0.5 to 10 tons of C/ha; and for agroforestry projects, it varies from 0.5 to 50 tons of C/ha.

These baselines, as discussed before, were estimated from current carbon stocks in the soil and in the vegetation. Higher carbon stocks are found in native forests suitable for SFM projects, and the lowest carbon stocks are found in areas suitable for plantation projects. Besides baselines, other criteria are used by potential CDM project buyers; these are presented in Table 7, using a comparative approach for each forest-based project.

CONCLUSIONS

This chapter discussed Brazilian programmes, currently being adopted, that are reducing carbon emissions and increasing carbon uptake. We also detailed additional mitigating forest-based initiatives that could be eligible for CERs from CDM projects. We argue that combatting deforestation, and the mitigating initiatives, such as reforestation and restoration of degraded areas and sustainable forest management practises, are not mutually exclusive, and do not compete for the same funds for their implementation. These funds could be raised through the CDM, as defined by the Kyoto Protocol (in December 1997), once proper analysis of project-specific eligibility and additionality takes place. In terms of reforestation and restoration projects in Brazil, resources from the CDM could serve:

- as a counterpart to private internal resources to

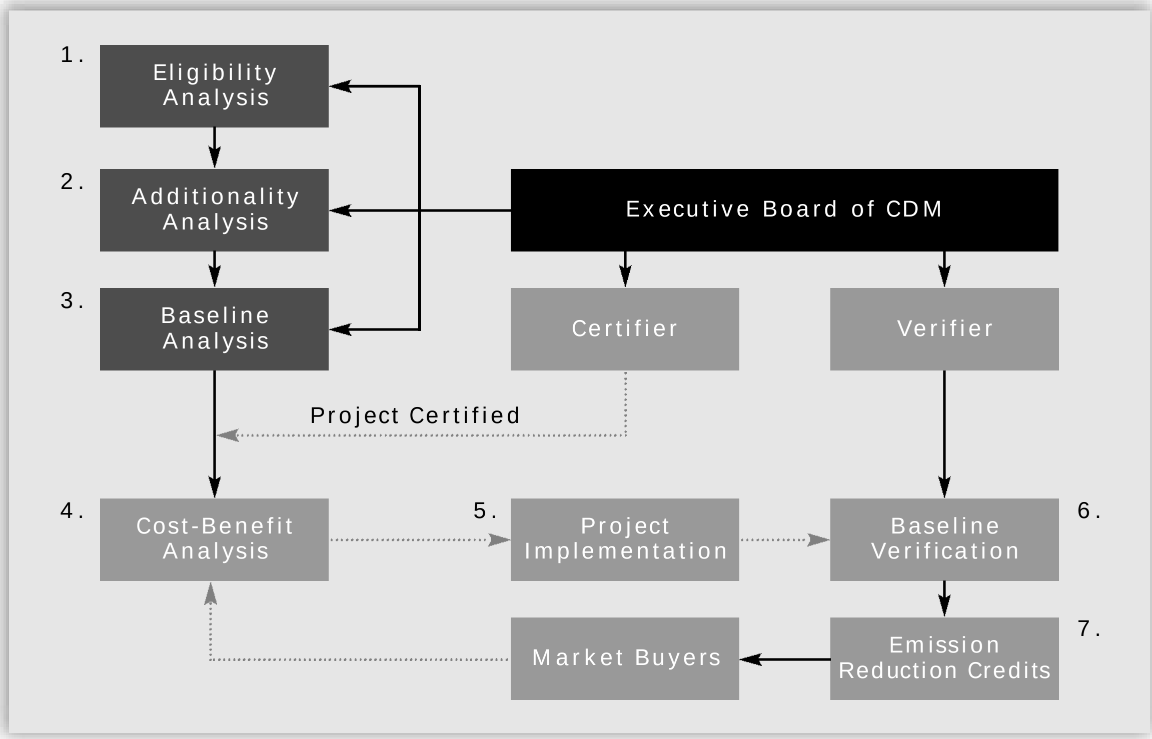
speed up projects already in progress, and to expand forestry-based industry
- as an additional funding source that might help for the maintenance of carbon stocks through SFM practices in the Amazon basin, restoration of gallery forests, and the implementation of agroforestry systems that could minimise further land use changes
- to promote the rehabilitation of degraded areas with native tree species

The forest-based initiatives presented in this chapter all have low opportunity costs, and can protect native species by using fast-growing trees, from plantations (afforestation projects). Some can also reduce reliance on fossil fuels by utilising wood gasification processes in the north east of Brazil, and by charcoal production. Project-specific carbon uptake costs were estimated, taking the scenario of no project implementation as a baseline and estimating current carbon stocks in the soil and vegetation. We also showed that forest-based projects in Brazil present viable CDM investment opportunities, which could result in the additional uptake of around 2 million tons of carbon per year.

ACKNOWLEDGEMENTS

The authors thank José Goldemberg for his ideas, comments, and revision of the text; Janet Jensen for editing the chapter; Walter Reid, José Otávio Brito and Michael Dutschke for their suggestions; Leandro Corrêa da Cunha de Siqueira for data searching; and Hebe Washington Peralta for her valuable assistance.

APPENDIX 1: EMISSION REDUCTION CREDITS STEPS FROM PROJECT-BASE ANALYSIS



This flow chart outlines the step-by-step way in which a CDM project-based analysis might proceed. It clarifies how a project could render credits of emission reductions, and how buyers of CERs from CDM projects will get these credits. For simplicity's sake, we have presented the process in seven linear steps. However, some steps could take place simultaneously or occur in a different order.

REFERENCES

Ab'Saber, A., 1990: Um plano diferencial para o Brasil. Estudos Avançados, **4,** 19-62.

Ab'Saber, A., J. Goldemberg, L. Rodes, and W. Zulauf, 1990: Identificação de áreas para o florestamento no espaço total do Brasil. Estudos Avançados, **4**, 63-119.

Amaral, W.A.N, 1994: Rio 92 and the Biodiversity Convention: Law and Environment at the Edge of the New Millennium. Harvard Law School, Cambridge, Massachusetts, pp. 23-35.

Anonymous, 1998: Dirt poor. The Economist, March **21,** Special Report, 1-16.

Apsey, M. and L. Reed, 1995: World Timber Resources Outlook, Current Perceptions: A Discussion Paper. Council of Forest Industries, Vancouver, BC.

Apsey, M. and L. Reed, 1996: World timber resources outlook: current perceptions with implications for policy and practice. Commonwealth Forestry Review, **75,** 155-159.

Barrichelo, L.E.G., 1990: O Floram em discussão. Estudos Avançados, **4,** 15-16.

Baumert, K., 1998: Understanding additionality. In this volume.

Binkley, C.S., 1993: Adapting to global supply constraints. In: The Globalization of Wood Processes, Products and Markets. University of Oregon, Portland, pp. 35-42.

BRACELPA, 1998: Custos de Projetos de Reflorestamento Intensivos. São Paulo, Brazil.

Brito, J.O.,1997: Fuelwood utilization in Brazil. Biomass and Bioenergy, **12,** 69-74.

Brooks, D.J.,1997: Demand for wood and forest products: macroeconomic and management issues. XI World Forestry Congress, pp. 93-102.

Brown, S. and A.E. Lugo, 1992: Aboveground biomass estimates for tropical moist forests of the Brazilian Amazon. Interciencia, **17,** 8-18.

Dixon, R.K. et al., 1994: Carbon pools and flux of global forest ecosystems. Science, **263,** 185-190.

Faeth, P., C. Cort, and R. Livernash, 1994: Evaluating the Carbon Sequestration Benefits of Forestry Projects in Developing Countries. World Resources Institute, Washington, DC.

FAO, 1997: Global Fibre Supply Study. Draft document. In press.

Fearnside, P.M. 1994: Biomossa das florestas Amazônicas brasileiras. Seminário Emissão x Emissão de Gas Carbônico. Companhia Vale do Rio Doce, Rio de Janeiro, Brazil, pp. 95-124.

Fearnside, P.M., 1997: Greenhouse gases from deforestation in Brazilian Amazonia: net committed emissions. Climatic Change, **35,** 321-360.

Fearnside, P.M., 1998: Forests and global warming mitigation in Brazil: opportunities in the Brazilian forest sector for responses to global warming under the "Clean Development Mechanism" and "Joint Implementation" programs. The Aspen Global Forum, p. 28.

Grainger, A., 1990: Modeling the impact of alternative afforestation strategies to reduce carbon emissions. In: Proceedings of the Intergovernmental Panel on Climate Change (IPCC) Conference on Tropical Forestry Response Options to Global Climate Change, São Paulo, Brazil. Report 20P-2003. US EPA, Washington, DC, pp. 93-104.

Houghton, R.A., 1994: As florestas e o ciclo de carbono global: armazenamento e emissões atuais. Seminário Emissão x Sequestro de CO_2, pp. 41-76. Companhia Vale do Rio Doce, Rio de Janeiro, Brazil.

IPCC, 1992: Climate Change 1992 — The Supplementary Report to the IPCC Scientific Assessment.

IPCC, 1995: IPCC Second Assessment. Contribution of Working Group II. Zynyowera, M.C., R.T. Watson, and R.H. Moss (eds.), WMO, UNEP. Cambridge University Press, Cambridge and New York.

Lino, C.F. (ed.), 1992: Reserva da Biosfera da Mata Atlântica. Editora da Universidade Estadual de Campinas, Campinas, Brazil.

Lugo, A.E., J.A. Parrota, and S. Brown, 1993: Loss in species caused by tropical deforestation and their recovery through management. Ambio, **22,** 106-109.

Macedo, A.R. P., C.A.L. Roque, and E.T. Leite, 1997: Produtos Sólidos de Madeira. BNDES Setorial (Ed. Esp.), pp. 157-176.

Marcolin, M., 1998: Avaliação das emissões de gases de efeito estufa devido as mundanças nos estoques de florestas plantadas. Seminário sobre Inventário das Emissões Brasileiras de Gases de Efeito Estufa. Fundação Brasileira para o Desenvolvimento Sustentado, Rio de Janeiro, Brazil.

Marcovitch, J., 1990: As origens do Projeto Floram. Estudos Avançados, **4,** 7-14.

Michaelowa, A. and M. Dutschke, 1998: Economic and political aspects of baseline determination in the CDM context. In this volume.

Nilson, S. and W. Schopfhauser, 1995: The carbon-sequestration potential of a global afforestation program. Climatic Change, **30,** 267-293.

Panayotou, T., 1998: Six questions of design and governance. In: Issues and Options: The Clean Development Mechanism. Goldemberg, J. (ed.). UNDP, New York, pp. 37-44

Parrota, J.A., 1993: Secondary forest regeneration on degraded tropical lands: the role of plantations as “foster ecosystems.” In: Restoration of Tropical Forest Ecosystems. Lieth, H. and M. Lohmann (eds.) Kluwer Academic Publishers, Dordrecht, the Netherlands, pp. 63-73.

Reid, W.V., and J. Goldemberg, 1997. Are developing countries already doing as much as industrialized countries to slow climate change? Climate Notes, July 1997, World Resources Institute, Washington, DC.

Reis, M.G.F., G.G. Reis, O.F. Valente, and H.A.C. Fernandes, 1994: Sequestro e armazenamento de carbono em florestas nativas e plantadas dos Estados de Minas Gerais e Espírito Santo. Seminário: Emissão x Sequestro de CO_2. Companhia Vale do Rio Doce, Rio de Janeiro, Brazil, pp. 156-195.

Rosa, L. P. and R. Schechtman, 1998: O sistema energético brasileiro. In: Comunicação Nacional do Brasil, MCT, in press. http://www.mct.gov.br/GABIN/CPMG/CLIMATE/PROGRAMA/PORT/natcomb.htm

Salati, E., 1994: Sumário Executivo: Emissão x Sequestro de CO_2: uma nova oportunidade de negócios para o Brasil. Seminário Emissão x Sequestro de CO_2, Companhia Vale do Rio Doce, Rio de Janeiro, Brazil, pp. 14-37.

Salati, E., and A. A. Santos, 1998: The Amazon and the Global Issues. Documento Fundação Brasileira para o Desenvolvimento Sustentado, Rio de Janeiro, Brazil.

Seppala, H., and V. Siekkinen, 1993a: Accounting system for wood-in-use as a carbon sink. In: The Globalization of Wood Processes, Products and Markets, University of Oregon, Portland, pp. 208-214.

Seppala, H., and V. Siekkinen, 1993b: Would radical carbon dioxide fees restructure future wood markets? In: The Globalization of Wood Processes, Products and Markets, University of Oregon, Portland, pp. 205-207.

Stassen, H.E., 1995: Small-scale biomass gasifiers for heat and power: a global review. World Bank Technical Paper, 296, Washington, DC.

United Nations, 1997: Kyoto Protocol: Global Climate Change.

Wilson, E.O., 1988: The current state of biological diversity. In: Biodiversity [E.O. Wilson and F.M. Peters (eds.)]. National Academy of Sciences Press, Washington, DC.

CHAPTER 8

Economic and political aspects of baselines in the CDM context

Axel Michaelowa
HWWA Hamburg Institute
for Economic Research
Hamburg, Germany

Michael Dutschke
HWWA Hamburg Institute
for Economic Research
Hamburg, Germany

SUMMARY: The efficiency of the Clean Development Mechanism (CDM) can be seriously hampered because both investors and hosts of CDM projects will seek to achieve maximum emission reduction. To avoid overstatement of emission reduction, it becomes necessary to define the emission that would have occurred without the project — the "baseline." This chapter describes several possible kinds of baselines and the problems posed by each. Country-wide base-lines offer the possibility of quantifying indirect effects through aggregation, but this must be balanced against the uncertainty of the assumptions required in an aggregate baseline. Sectoral baselines are as problematic as sector boundaries are arbitrary. Thus, project-specific baselines with sectoral elements are recommended as a basis for the CDM.

INTRODUCTION TO THE CDM

Greenhouse gases affect the atmosphere on a global level — the location of the emitter is not relevant. International climate policy-makers, however, face the dilemma that only OECD and Eastern European countries have committed themselves to quantitative emission targets in the Kyoto Protocol, whereas the developing countries, with prevailing high emission intensities and low abatement costs, have not accepted such targets. Therefore, the Protocol instituted a mechanism to grasp reduction opportunities in the latter countries: the so-called Clean Development Mechanism (CDM). Article 12 of the Kyoto Protocol outlines the CDM. Its third paragraph states that investing countries get credit for certified emission reductions (CERs) from CDM projects, provided "benefits" accrue to the host country (Art. 12.3[a]). Crediting shall only be allowed "to contribute to compliance with *part* of their quantified emission limitation and reduction commitments" (Art. 12.3[b], emphasis added), a "part" that remains to be defined. It is unclear whether crediting up to this quota is on a discounted basis. CERs are tradable under Article 3.12. Not only countries but companies as well are allowed to invest and execute projects (Article 12.9). The CDM will cover its administrative budget through project revenues. Moreover, a "part" of these revenues shall be used "to assist developing country Parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation" (Article 12.8). Who does certification of emission reduction remains open to question, but verification will be done by independent bodies (Article 12.7). The project criteria remain the same as for Activities Implemented Jointly (AIJ) (Article 12.5).

The theoretical efficiency of reaching domestic emission targets through less costly reduction measures abroad is widely accepted. Nevertheless, the CDM can be distorted through actions of different interest groups, leading to inefficiencies and spurious claims for emission reductions (Michaelowa and Greiner, 1996). Therefore, every detail of the CDM has to be carefully designed to avoid pitfalls. Experiences from the AIJ pilot phase should be taken into account. Even without crediting for emission reduction achieved through AIJ projects, there was a temptation for the participants to overstate emission reduction in order to foster support for the instrument. The lack of investment in the pilot phase has shown the necessity of incentives for investors. For a discussion of incentives, see Michaelowa (1996).

Many countries still express many reservations concerning crediting of CDM projects. They will support the CDM only if its design prevents cheating and leakage, and takes account of uncertainties (Hagler-Bailly, 1998b, pp. 1-6) in order to avoid spurious emission reductions. From the systematic point of view, the CDM itself is a loophole because it allows the Annex B countries — those that have taken on legally binding reduction commitments — to inflate their cumulative targets. Therefore, it is imperative to define mechanisms that lead to real and measurable emission reductions. To calculate these reductions, the concept of baseline is paramount. A baseline is a quantifiable business-as-usual scenario. Allowing the sale of CERs on the international market for emission permits requires firm baselines and puts strict requirements on certifiers.

THE BASELINE: THE CRUCIAL ASPECT IN THE DESIGN OF THE CDM

If the CDM host countries had quantitative targets themselves, there would be no need for baselines. But without them, the credibility of the CDM depends on the degree it succeeds in reducing greenhouse gas emissions and avoids fictitious emission reduction reporting. The amount of emission reduction, obviously, depends on the emissions that would have occurred without the project. The construction of such a hypothetical state is known as the "baseline" of the project (Pearce, 1995, p. 27). However, various problems arise in developing a scenario that will never actually take place.

Often there is confusion about the differences between the definitions of "additionality" and "baseline." We define the "baseline" as the overarching concept. The determination of whether a project is additional or not comes from calculating the difference between the verified emission of the project and the baseline emission. If the latter is higher, the project is "additional."

GENERAL FORECASTING UNCERTAINTY

A major obstacle to defining a baseline is that the emission levels have to be forecast for the entire lifetime of the related project. In the case of carbon sequestration projects, the lifetime can be up to a century. Forecasting emission levels for such a long period amounts to guesswork. The differences among the various scenarios sketched by the Intergovernmental Panel on Climate Change (IPCC), for example, reach an order of magnitude (Houghton et al., 1992). But even for short-term projects (lasting five to ten years), it seems impossible to calculate an accurate baseline. The difficulty of business cycle forecasting is well known. Structural shocks can wreak havoc with a forecast: take, for example, an Eastern Europe development forecast in 1988 or an East Asian growth forecast of 1996. The question is, on the other hand, whether requirements for the CDM baseline have to be higher than for the Annex B targets. These targets, fixed in December 1997 for emissions in the years 2008 through 2012, are themselves based on a high degree of uncertainty.

TREATMENT OF “NO REGRETS” PROJECTS

Already, many emission reduction opportunities are profitable to undertake — either for a company or for a country as a whole. The profitability for the latter includes externalities, such as the reduction of other pollutants. Now the question arises as to whether these so-called micro- or macroeconomic “no regrets” projects — projects that would seem to be profitable on their own — should be included in the baseline. So far, the question of “no regrets” opportunities has led to heated debates in the economics community. Some say that there can be no “no regrets” projects because such opportunities would have already been exploited (Sutherland, 1996). Others estimate that 10%-30% of today’s emissions could be reduced by means of “no regrets” projects (IPCC, 1996).

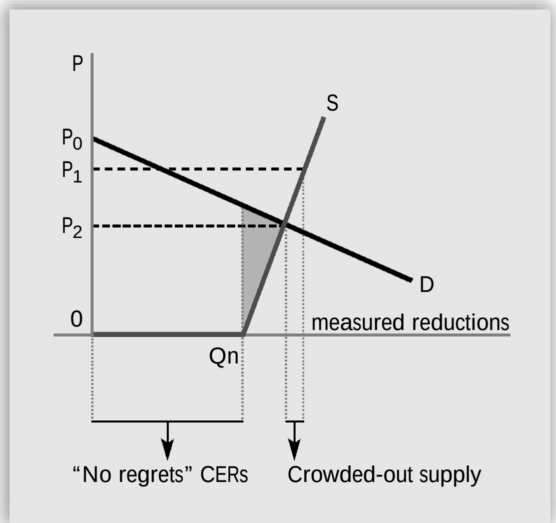
These differences arise from the fact that — despite the theoretical profitability of many options — such projects face regulatory and legal obstacles, or are encumbered by a lack of information or skilled personnel, or by organisational rigidities. It is often reported that managers do not invest in promoting energy efficiency — even if its internal rate of return is much higher than the prevailing market interest rate. The main reasons are probably short planning periods, requirements for a minimal rate of return much higher than market interest, and lack of capital. Another factor is the investor’s planning security as far as political and fiscal conditions are concerned. It is not surprising that private households have even higher thresholds for internal rates of return. In particular, this applies to countries in transition and developing countries. Often an investor cannot appropriate a gain, as it is an externality accruing to others. Therefore, it seems that pure microeconomic “no regrets” opportunities are quite scarce, whereas macroeconomic “no regrets” opportunities abound. In a similar vein, Heller (1998, pp. 11ff) contends that transaction costs often inhibit “no regrets” projects.

So far, emission reduction projects have not been funded by countries — even if they clearly fulfil macroeconomic “no regrets” criteria. A good example is the ILUMEX project in Mexico, which would lead to a macroeconomic gain of US$0.05/t CO_2 by distributing subsidised compact fluorescent lamps, with the gains accruing to the participating households. Furthermore, the project accelerates the development of a market for the lamps. From a microeconomic perspective of the Mexican utility, however, the project has net costs of US$30/t CO_2 (Anderson, 1995, p. 10). Similar examples also occur in the industrial countries. The abolition of coal subsidies in Germany, for example, would surely be a macroeconomic “no regrets” project of considerable magnitude (Michaelowa, 1995, p. 33).

Until now, the “no regrets” issue typically has been referred to in very general terms in the debate on the CDM and AIJ. While some authors say that all “no regrets” projects have to be included in the baseline and therefore excluded under the CDM (Bedi, 1994), others would accept all of them (van der Burg, 1994; Rentz, 1998). Chomitz (1998, pp. 3ff) presents a macroeconomic analysis of their inclusion, without taking into account the barrier question.

A possible criterion for inclusion in the baseline could be whether a project is a microeconomic “no

FIGURE 1: Effects of Accepting “No Regrets” Projects



Source: Chomitz (1998, p. 3).

Note: The “no regrets” CER supply price is zero. As a result, world GHG emissions increase by Qn, because buying countries are allowed to increase their emissions by this amount. Presumably the damages from these emissions exceed the savings in buying country’s abatement costs (the area under the demand curve from 0 to Qn). The gains from CDM activities, shown again by the shaded triangle, are reduced. Some relatively high cost suppliers of CDM projects have been crowded out of the market. The remaining suppliers have seen their rent per ton reduced by P_1-P_2. In this analysis, overstated baselines result in increased emissions, reduce the gains from CDM, and divert rents away from projects with positive costs.

regrets" project. If such projects were excluded from the CDM, an investor would have an incentive to artificially raise costs to demonstrate that his project has positive net costs (Torvanger et al., 1994, p. 21). Therefore, even that distinction cannot be applied.

The International Energy Agency (1997) tries to define barriers to project implementation. It suggests that a project be accepted under the CDM if it promises to overcome technological, financial, or institutional barriers. This is the best proposal to evaluate the "no regrets" issue, but even here one can define barriers quite arbitrarily. Chomitz (1998) tries to quantify the barriers through behavioural and financial modelling. He states, however, that the parameters from which to create these models are known only to the project sponsor and can easily be manipulated. Thus, he argues for default specification of these parameters on a country-by-country basis.

Heller (1998, pp. 15ff) argues that a qualitative screening for transaction costs and barriers should be a sufficient criterion for key projects that prevent lock-in of energy-intensive infrastructures on a substantial scale to qualify for CDM.

POLITICAL DISTORTIONS OF BASELINES

The problems in establishing country-related baselines have also been felt in the business as usual projections in the national reports of the signatories of the United Nations Framework Convention on Climate Change (UNFCCC). Country baselines are necessary for determining reduction targets within the framework of international negotiations. Substantial evidence can be found that countries tend to overstate business-as-usual emissions, which can be used to negotiate from a position that offers a high reduction from the spurious baseline (Jochem et al., 1994). If realistic baselines cannot be established, not only the CDM but also any other form of controlled greenhouse gas reduction policy becomes impossible. Thus, Heller (1998, p. 12) argues for baselines that prevent the prolonging of inefficient economic structures.

The calculation of country-related baselines and aggregate reductions resulting from CDM projects is therefore fraught with uncertainty. However, since these problems also arise in the determination of national reduction targets and the development of policies to reach them, this uncertainty cannot be used as an argument against the CDM.

INCENTIVES TO CHEAT

Investors and hosts of CDM projects — companies as well as countries — have the same interests. They want to get a maximum emission reduction through the project. The gain for the investor depends on the ratio of total project costs and certified emission reduction. The host will only find an investor if the project leads to a gain for the investor (Barrett, 1995, p. 9). Therefore, the host is likely to overstate the possible emission reduction. As the gain depends on the amount of the certified emission reduction, there is an incentive to over-report emission reduction during the project. This also enhances the possibility of getting investors for future projects.

Obviously, cheating will be widespread if the projects are not carefully monitored and verified. Even if projects are well monitored, the real emission reduction might still be lower than the certified reduction. The longer the project's duration, the higher the uncertainties about its baseline. Cheating by individual project participants would become difficult if a country-related baseline was used; but in that case, the host country government could try to set the parameters in a way that amounted to political distortion — that is, cheating on a macro scale.

Deliberate overstating of emission reduction would become rather difficult if an internationally agreed upon method were used to calculate the emission levels of a country in the absence of a CDM project. A single standardised methodology for designing forecasting models and collecting

TABLE 1: Possible Baselines

	Baseline definition	Cost of drawing up the scenario*	Depiction of reality	Emission reduction indicated
Country level	Constant emissions based on historical levels	Very low	Very poor	Much too low
	Linear extrapolation	Low	Relatively good	Too high if growth rate decreases, too low if growth rate increases
	Forecast based on economic development and population growth	Very high	Good	Correct if the assumptions are realistic, too high if the assumptions are overly optimistic
Sector level	Sector-specific	Rather high	Relatively good	Correct if indirect effects do not cross sector borders
Project level	Project-related scenarios with sector-related project typologies	Low	Good	Correct if project typologies cover indirect effects
	Individual project-related scenarios	Low or high (depending on detail)	Relatively good	Correct if indirect effects compensate for each other

* These costs are incurred by different agents: In the more highly aggregated cases, costs are more likely to fall on public agencies than on the project participants. This tends to lower transaction costs for the latter. Moreover, some costs are recurrent (especially on the project level), while others occur only at long intervals. The aggregated approaches will lead to higher up-front costs but probably to lower operating costs. Thus, the entries should be considered as rough approximations of the magnitudes involved.

data would be required, to be drawn up by the Subsidiary Body on Scientific and Technological Advice (SBSTA) of the UNFCCC (for a first preliminary collection of guidelines, see UNFCCC, 1997, pp. 2-7). Baseline development should be subject to the review of independent certifiers — any creation of CERs would take place only after examination of the baseline. It is also important to guarantee transparency and NGO participation in the process of setting baselines (Chomitz, 1998, pp. 53ff). The SBSTA states that “all AIJ require project-specific baselines. The methodologies used in calculating the baseline scenario may be sector-specific, technology-specific or country-specific” (UNFCCC, 1997, p. 2).

Below, we compare country-wide and sector- and project-specific approaches. Baselines here are understood to be absolute values in tons, not rates. Table 1 summarises their characteristics.

DIFFERENT TYPES OF UNCERTAINTIES

Even if there is no deliberate attempt to cheat, different types of uncertainties exist concerning the baseline:

- political uncertainties — e.g., whether subsidies will be phased out
- economic uncertainties — e.g., whether good policies put the country on a higher growth path or an external economic shock occurs
- technological uncertainties — e.g., which technologies might have been chosen without the project
- cost uncertainties — e.g., whether the project is a “no regrets” project.

One has to take into account that these uncertainties occur on different levels of aggregation: while 1 and 2 are primarily relevant on a country level, 3 relates to the sectoral level and 4 to the project level.

But 1 and 2 can have effects on the project level too, depending on the level of capacity utilisation.

It is impossible to develop baselines with no uncertainty whatsoever. However, we can evaluate them on the basis of whether they have a higher inherent uncertainty than a domestic climate policy.

STATIC VERSUS DYNAMIC BASELINES

The problems created by fixing baselines for projects with long lifetimes could be alleviated through “dynamic” baseline calculations, which would be adjusted to take policy and macroeconomic changes into account (Andrasko et al., 1996). “Dynamic” baselines would result in increased uncertainty for the investors, because the credited emission reduction would depend on the adjustments of the baseline (UNFCCC, 1997, p. 3). However, baseline regulations should limit, but not abolish, the entrepreneurial risks (and chances!) the investor takes. Emission reduction benefits should be useful to overcome initial investment barriers, but they must not serve as a subsidy for an otherwise unprofitable project over its entire lifetime. A dynamic baseline could even fulfil the developing countries’ demand for the transfer of state-of-the-art technology, by discouraging “dumping” of outdated technology to the host country. If, for instance, a CDM project consists of replacement of a coal-fired power station by an efficient renewable plant, the difference will not only be higher but also longer-lasting than just retrofitting the old plant. Dynamic baselines need not be over expensive if they rely on a set of easily observable variables (Chomitz, 1998, pp. 22-23).

A possible compromise would be regular updating of the baseline — once every five years, for instance — or the option of a fixed, but more conservatively calculated baseline (Hagler-Bailly, 1998b, pp. 1-9). The maximum lifetime of a baseline could be set at a decade. While annually updated baselines could be rewarded by certifying 100% of the emission reductions, this ratio could decline for projects with longer updating periods. In the second year of use of a baseline, for instance, 95% of the emissions reductions would still be recognised as certifiable. Following this example, in year 10 only 55% of the emission reductions calculated against the old baseline would be certified. Starting with year 11, a new baseline would have to be established for the project. This model serves to create a level playing field for project types different in measurement and duration.

COUNTRY-WIDE BASELINES

An ideal country baseline would be an overall emission cap, comparable to the Annex B targets. Intra-country leakage would be zero and the “no regrets” issue sidelined. Nevertheless, this is not politically feasible, because host countries are wary of committing to anything like a cap. It seems very appealing to calculate a baseline for a whole country and then aggregate the effects of the different CDM projects (Ardone et al., 1996). For CDM host countries, we would expect a growth baseline. Reliable, quantified measurements of actual emissions are an important prerequisite for establishing such a baseline. A number of very different approaches are currently used to this end, producing highly divergent results (Michaelowa, 1995, pp. 63ff). Hamwey (1997) simply averages historical emission factors. The study by Rentz et al. (1998) used energy systems models to derive baselines for Russia and Indonesia. However, because of the lack of data and data reliability problems, the Russian model does not consider industry and the household sector (Rentz et al., 1998, p. 160) — it covers only the energy supply and forestry sector. Obviously, such a baseline will be misleading. The Indonesian model at least covers the electricity demand side, but not transport fuel or heat demand (Rentz et al., 1998, pp. 184ff).

Country-wide baselines could be necessary if macroeconomic reforms such as subsidy phase-out were allowed to count as “projects” under the CDM (Center for Clean Air Policy, 1998).

SECTORAL BASELINES

A growing stand of literature (Carter, 1997; IEA 1997; Wirl et al., 1996) proposes sector-specific baselines. This conceptually simple, politically difficult solution would establish sectoral or national caps, and measure offsets against these (Carter, 1997). This is particularly appealing for large-scale projects with significant sectoral effects. For instance, a decision to build a generating plant can affect grid-wide expansion and generation plans. Similarly, project-based efforts to protect particular forest plots from subsistence-oriented conversion might merely divert the converters to another location. For large-scale energy and forestry projects, it could be desirable to compute sectoral level baselines and look at sectoral level effects. Sectoral baselines would have to be developed beforehand by the host country's institutions. This labour could be financed by GEF, thereby lowering transaction costs for potential investors.

Among the several severe difficulties in pursuing this approach is establishing the overall cap. This could be accomplished through the use of a complex model of the energy sector or of land use, based on prior emissions levels, adjusted for population or economic growth. In general, agreement on such a cap might be very difficult. A second difficulty arises in allocating the rights to create offsets against this cap. Moreover, the informational requirements can be very high, especially in a developing country context. Finally, it is unclear where sector boundaries should be set. Nevertheless, the sectoral approach should be chosen in the context of sink projects where leakage through simple relocation of forest destruction or degradation is very likely.

Qualitative sectoral baselines have also been proposed. These could be expressed by the ratio "carbon emission divided by energy output," which, according to the sector, would translate into "fuel per ton kilometre" or "CO_2 emission per kW/h of electric energy." This would not limit the absolute rise of emissions and would therefore address developing countries' concerns over being hampered in their economic growth. The advantage of qualitative sectoral baselines is highlighted by the extreme case of a power plant that is built but never operated — it would not yield any credits. Using such baselines, increased sector production would lead to higher credits for the investing country only if the plant increased the overall efficiency. In many cases, this ratio is comparable between developing and industrialised countries. As high-energy efficiency is a precondition for limiting CO_2 emissions, qualitative sectoral ratios could be used as common (and perhaps voluntary) targets for all Parties to the UNFCCC. However, this condition is necessary but not sufficient. The whole industrialisation process has been marked by an increase in resource efficiency, which led to higher profits instead of diminished pressure on the resources. It would be counterproductive if industrialised countries were allowed higher absolute emissions while non-Annex I countries increased their absolute emissions as well. Apart from damaging the atmosphere, this would erode the value of CERs. Therefore, mixing qualitative and quantitative targets does not lead to the desired results.

Nevertheless, common efficiency ratios of all Parties would motivate host countries to press for higher efficiency standards when accepting a CDM project. With the absolute emission reduction credits going to the investing country, the host country would profit in attaining its qualitative goal.

PROJECT-RELATED BASELINES

While country or sector baselines are often financed by host country institutions, project-related baselines are most likely to be financed as part of the transaction costs by the investor, who could try to influence the outcome of the baseline study. Therefore, they tend to be feasible only for larger projects. The problem is that investors could try to influence the outcome of the baseline study. Taking into account the uncertainties of country-related baselines, project-specific baselines have been proposed as an alternative (Roland and Haugland, 1995, pp. 361ff; Michaelowa, 1995, pp. 65ff; Luhmann et al., 1995).

The calculation of the business-as-usual scenario has to account for likely changes in relevant laws and regulations, the overall trend for efficiency improvements, and changes of other basic variables, such as development of markets for products of the project. It is possible to define either a "median" baseline or a set of baselines with different assumptions weighted according to their probability (Andrasko et al., 1996). For example, if a power station project does not replace an existing plant but creates additional capacity, the baseline depends on the fuel that could have been used in an alternative solution. The alternative to a hydro-electric power station can be a coal-fired power station, for instance, burning either hard coal or lignite and producing very different emissions. For practical reasons, the host country's average fuel mix should be chosen for calculating the baseline in such cases (Michaelowa, 1995, p. 65). The choice of such benchmarks is discussed by Hagler-Bailly (1998b, pp. 3-11ff), who discusses four ways of defining benchmarks: historical, forward-looking, and small and large samples.

The problem of defining an alternative project does not arise if, for example, an existing plant is to be replaced.[1] In that case, the question of the remaining lifetime of the replaced plant has to be answered. Chomitz (1998, pp. 6ff) lists a number of parameters that influence this value and finds them hard to observe, and subject to misrepresentation, strategic manipulation, and autonomous change.

Before the quantitative impact of a sequestration project can be estimated, relevant sources and sinks of greenhouse gases must be identified. Moreover, a quantification of past emissions is necessary.

Demand-side management (DSM) projects pose special challenges, as they rely particularly on behavioural parameters. Nevertheless, the experience with US DSM has led to valuable progress in determination of actual energy savings that can be transferred to baseline determination (Chomitz, 1998, pp. 14ff, 39ff).

To correct the estimates for "free riders" — those who would have installed the subsidised measures anyway — evaluators often use survey instruments. Remarkably, a significant proportion of the respondents acknowledge that they would have adopted the measures without any incentives. Another approach uses control groups. For instance, if high-efficiency light bulbs were subsidised through a CDM project in one city but not in an otherwise completely comparable control city, monitoring the latter would provide baseline information about the spontaneous rate of adoption of the bulbs in the absence of incentives. However, valid control groups are difficult to find because valid statistical comparisons require a large sample size for modest changes in emissions to be detected. Moreover, in many cases, the project facility may be unusual, and it may be difficult to find a large enough or similar enough control group to permit these comparisons. The control group has to be ineligible for, and likely to be unaffected by, the project.

LEAKAGE

Project-specific baselines do not take into account indirect effects that can arise, for instance, when the project no longer produces but buys goods whose production caused greenhouse gas emissions. Emissions can also be influenced by price effects. For example, when carbon-rich fuels are substituted by low-carbon fuels, the price of the former tends to fall while the price of the latter will tend to increase. This price effect, in turn, tends to stimulate greater use of carbon-rich fuels and lead to an increase in emissions. Demand-side energy savings would also cause energy prices to fall.

Another indirect effect would be the alleviation of energy supply shortages in host countries. (Heister and Stähler, 1994). This argument is static,

---

[1] *Luhmann et al. (1995, p. 6) come to a different conclusion concerning power plants as substitution processes if the electric grid would lead to changes in the operating schedules of other power plants. Therefore, they chose hypothetical reference power stations as baseline. If the new plant is used for the same load as the old one, their argument seems unconvincing. It becomes valid only if there is a change from peak load to base load, for example.*

however. If one assumes rising incomes in these countries, these shortages would be alleviated in any case without emission reduction policies. It is possible, though, that industrial countries could try to push strongly for the extension of electricity supply in developing countries to enhance their own export markets for power supply technology. In this case, even the supply of efficient, state-of-the-art technology would lead to additional emissions compared to a business-as-usual path. Nevertheless, the emissions from additional electricity use would certainly be at least partly offset by reduction of emissions from unsustainable fuel-wood collection.

Therefore, an indirect effect of CDM projects might be to raise emissions in the short term but to lower them in the long term. It is likely that the latter effect would be greater. However, these indirect effects can only partially cancel out the emission reduction achieved by a CDM project. The effects described above arise in any sort of climate protection project and not just in the case of CDM. Moreover, improved access to modern technology through the CDM can contribute to emission reductions. The same applies if products of the project sequester greenhouse gases and substitute for energy-intensive goods. It is impossible to specify whether indirect effects will lead to more or less emission reduction than the project-specific baseline scenario suggests. Thus, in the case of undistorted markets, there is no systematic trend for project-specific baselines to show excessive emission reductions. This is not taken into account by SBSTA (UNFCCC, 1997, p. 2), which states that “system boundaries for AIJ projects should be appropriate to the scale and complexity of the activity, so as to incorporate consideration of possible leakage.”

Nevertheless, leakage could be taken into account by deducting a certain percentage of leakage by default from the certified emissions reduction, depending on the type of project. The penalty such an approach exacts from low-leakage projects could be reduced by allowing project participants to get up to the full amount of certified emission reduction units if they can prove that leakage is lower than the default specification.

INEFFICIENT GOVERNMENT POLICY

Besides indirect effects, a problem with project-related baselines arises if the host country distorts fuel and electricity markets by granting production or consumption subsidies. A project-related baseline cannot take into account changes in these subsidies that would alter a country-related baseline. As tight public budgets and liberalisation of energy markets lead to subsidy cuts, project-related baselines would show greater emission reduction because of the higher incentive to save energy when energy prices rise. Thus, after phase-out of subsidies, we would forecast a lower country-wide baseline. A solution to this problem could be to prescribe a combination of a country-wide baseline with project-specific ones, which would allow for adjustment of the latter if the subsidies were phased out. This combination should be used only in cases of high subsidies or market distortion. It should be taken into account, however, that such a solution would provide a disincentive to phase out subsidies, because the amount of CERs would be positively linked to the amount of subsidies.

PROJECT LIFETIME

SBSTA proposed that projects with equity financing should use the engineering or operating lifetime of the project, whereas projects with debt financing should use the amortisation or depreciation lifetime of the project (UNFCCC, 1997, p. 3). Choosing the operating lifetime could eventually lead to running an outdated plant only because it generates emission reduction units. The amortisation lifetime usually is too short a period to make use of the plant’s full benefits. We therefore propose the commercial lifetime of the project’s hardware as an intermediate measure, in order to keep the investment certifiable as long as it remains commercially profitable.

In the past few years, some 100 AIJ projects have been proposed world-wide, and a sizeable share has already been implemented. Therefore, the theoretical debate on baselines can be supplemented by examples from "real life." Neither the baselines of current projects nor the simulation studies include "no regrets" opportunities in the baseline. Nevertheless, part of the database is inadequate, and remains to be improved before the end of the pilot phase. Often, the baseline methodology is not explained in detail. Because of lack of financing, many projects whose baselines are discussed below have not yet been implemented.

The first European projects that typify large-scale forestry efforts under the CDM are the afforestation projects of the Face Foundation in the Netherlands. These projects use a very simple baseline: the state of the region without forest cover or the existing, damaged forest. Indirect effects are not taken into account. The sequestration is then calculated with a computerised sequestration model using data from a small number of field studies (Face Foundation, 1995, 1996).

The US Initiative on Joint Implementation (USIJI) developed several criteria for baseline definition (USIJI, 1996, p. 12). It states that baselines have to be consistent with:

- prevailing standards of environmental protection in the host country
- existing business practices within the particular sector of industry
- trends and changes in these standards and practices.

It also stipulates that baselines must include indirect effects such as activity shifting, price effects, and life-cycle effects in products, and that they provide information on other environmental effects of the project.

The descriptions of 15 USIJI projects include detailed baselines (USIJI, 1996). Despite the criteria, indirect effects have not been covered to any extent. Changes in the legal framework are covered only in some projects; others do not take them into account.

It is particularly interesting that most of the forestry projects try to define baselines for afforestation and preservation of existing stocks without accounting for sequestration/emission of the soil, considering the fact that uncertainty about this remains high. There are two exceptions — the ECOLAND project in Costa Rica and RUSAFOR in Russia. In the ECOLAND case, the soil carbon makes up 44% of the whole emission reduction estimates (Dutschke, 1998, p. 78).

In the Belize Rio Bravo project, it is unclear whether the baseline deforestation rate is just an extrapolation of the historical rate or a "best guess." In most Costa Rican projects, the extrapolated rate is used. In case there are uncertainties about existing stocks on deforested lands (which can easily reach an order of magnitude), the BIODIVERSIFIX project chooses the upper boundary as baseline, while CARFIX sets the stock after deforestation to be zero. The difference is substantial: 10 t C/ha. If BIODIVERSIFIX had chosen the same baseline value as CARFIX, its total emission sequestration would have been 585,000 tons higher. In the former project, which entails the purchase of land, the lifetime is restricted to 50 years, though the equilibrium will only be reached in a century, therefore reducing the accountable carbon storage by 30%, or almost 2.2 million tons. CARFIX project does not involve purchase of the land, and is assigned a lifetime of only 25 years; but there is no guarantee that the afforested areas will not be cut after the payments to the participating farmers end. The RUSAFOR project established three different baselines but did not make them public. It chose as the "most probable" scenario the one that also forecast the highest emissions.

Renewable project baselines do not include life-cycle emissions of the plant material. An interesting consequence of the renewable energy projects in Costa Rica is that because of the Costa Rican Government's commitment to phase out fossil fuel electricity production by 2001, the baseline is zero emissions after 2001. USIJI doubts whether the government commitment can be fulfilled, but nevertheless requires the baselines to take this commitment into account. This means that renewable energy projects in Costa Rica will not become creditable under the CDM regime after 2000. Therefore, all the renewable energy projects now approved are likely to be "no regrets" projects. The fossil fuel baseline for Costa Rica assumes that fossil fuel emissions remained constant from

TABLE 2: Examples of Baselines for DSM

Measure	Baseline approach	Free rider	Leakage	Takeback	Persistence
Residential new construction	Statistical analysis (comparison area), builder survey inputs for engineering model	Builder survey, sales data, or survey in comparison area	Time series comparison of building practices, builder survey, survey in comparison area	Statistical bill comparisons or home-buyer survey	Persistence not a significant issue compared to other DSM measures
Engineering analysis for small/informational programmes; multivariate regression recommended for most incentive programmes.					
Residential envelope	Statistical analysis (pre/post or comparison groups), engineering analysis with on-site surveys	Survey (participants or both participants and non-participants)	Similar to residential new construction	Survey questions could address takeback issues	Not important for relatively permanent measures (insulation and window improvements), important for caulking and weather-stripping
Building simulations would be appropriate for small or informational programmes, and statistical or integration methods are more appropriate for direct installation and incentive programmes. Load programmes, which require participants to complete much paperwork, are more susceptible than low-income weatherising programmes.					
Residential refrigerators	Time series billing and metering data can be used for buy-back programmes but not new dwelling installations; engineering analyses can use standard efficiency levels as baselines	Pre-programme sales (e.g., dealer survey) or participant surveys for incentive programmes, participant surveys for buy-back programmes that purchase second refrigerators	Survey (dealers, participants, or both participants and non-participants)	Participant surveys can ask whether incentive led to different purchase or if new refrigerator was purchased earlier than planned and old refrigerator was kept as secondary refrigerator	Persistence is likely for efficient units but uncertain for buy-back programmes
Statistical analysis for incentive programme will lack pre-participation data on alternative refrigerator purchase, but engineering methods can use labelled usage data for comparable, non-qualifying models. Buy-back programmes are amenable to statistical methods because savings are potentially large and pre-programme data exist.					
Commercial lighting	Engineering methods with survey or site-based data on baseline technologies and usage levels; statistical or combination methods may be justified by large expected savings	Can be large for lighting programmes, use participant surveys; comparison groups can be difficult to identify	Survey (participant, or participant and non-participant) and equipment dealer surveys	Not likely to be a significant factor	Malfunctioning systems, tenant turnover, and remodelling affect persistence
Engineering methods are commonly used for lighting programmes, with SAE methods used for larger programmes.					
Industrial motors	Engineering methods or time series comparisons are commonly used	Can be large, especially among large participants, use participant and dealer surveys	Can be large, survey non-participants or estimate market saturation levels	Not likely to be a significant factor	Generally persistent over motor lifetime
If greater precision is required, time-series comparison approaches of end-use metered data are most appropriate. Identifying baseline activity (new motor, rewind existing motor, continued use of existing motor) is important.					

Source: Hagler-Bailly (1998a).

1994 to 1997; that they would decrease by 44% in 1998, 86% in 1999, 99% in 2000, and 100% in 2001 (Dutschke and Michaelowa, 1997, p. 34). The figures chosen differ for 1998 and 1999, however, as some projects take 33% and 66% reductions, respectively. These numbers depart from constant energy demand. In reality, Costa Rican electricity demand has been growing constantly by about 8% annually (*ibid.*).

A biomass-fired plant in Honduras will replace a fossil-fuel power plant. This project has a rather uncertain baseline. The project lifetime of 20 years seems long. Moreover, there is a huge demand for electricity in Honduras. Therefore, it is unlikely that the existing fossil plant will be shut down. In the baseline, it is assumed that the biomass would not be used. The possibility that deforestation will rise to supply biomass to the plant is not considered.

Small-scale solar electrification in rural Honduras defines average kerosene burning in lamps as the baseline. This baseline seems to be conservative, because the solar panels can also be used to recharge batteries that substitute for dry cells.

Interestingly, the baseline for a geothermal power station in Nicaragua is based on hypothetical diesel-fuel power plants with a lifetime of 35 years (assuming rising power demand). Emissions from the geothermal power station are taken into account.

The RUSAGAS project, which entails sealing of valves on natural gas pipelines, takes current emissions as the baseline and estimates a lifetime of 25 years. This baseline seems questionable, though, because the regulatory frame is likely to change during that time. So far, the Russian gas company is paid only for the quantity of gas extracted but not for the quantity delivered. If the latter situation applied because of regulatory changes, the incentives to seal the valves would be very high for the company. That means that the baseline would then have to be set at zero.

A co-generation project in Decin in the Czech Republic uses a projection of heat use. It projects a decrease in demand by 13% in 2001 and a constant demand thereafter. The existing coal-fired power plant was taken as baseline for heat production. Moreover, the existing average emission factor of the Czech electricity production was taken as baseline for the electricity production of the new plant. That seems to be overly optimistic, as this emission factor will surely be reduced in the business-as-usual case because of reduction of subsidies.

Many Swedish small-scale boiler conversion projects in the Baltic States take the status quo before project implementation as baseline (Center for Clean Air Policy and SEVEn, 1996, pp. 60ff). This does not take into account subsidies and market distortions. A phase-out of the subsidies would make many of these projects profitable and thus part of a country-wide baseline.

BASELINE SIMULATION

The Nordic Council of Ministers has used five existing projects in Eastern Europe as models of Joint Implementation. While focussing on the differences in costs and performance among project designs, they also examined the projects in terms of baseline issues (Nordic Council, 1996, pp. 28ff). Sectoral official development plans are considered appropriate baselines for power plant projects, whereas in the heat sector some efficiency improvements are predicted. In the case of the Czech Republic, for instance, a draft law on heat metering and thermostats is expected to lead to business-as-usual improvements. In other locations, the availability of substitute fuels defines the baseline. In several cases, continued operation of the existing plants was considered unlikely. Therefore, the new projects would have been undertaken in any case at some point, and by that time baseline emissions would equal the project emissions. In the case of a geothermal heating plant in Pyrzyce, Poland, there were five realistic baselines considered — with emissions that varied by a factor of 5. The choice depended on the probability of certain conditions. The calculation of one of these baselines shows how complicated it can be to define whether a project is “no regrets” when an effort is made to take externalities into account (Chomitz, 1998, pp. 9ff).

The project involved an investment of US$15.31 million over two years. After this start-up period, it should deliver estimated annual savings of US$890,000 in fuel costs, US$130,000 in maintenance costs, US$1.97 million worth of SO_2 and NO_X reductions, and 68,618 tons of CO_2 reductions. Drawing on the data presented by the Nordic Council of Ministers (1996), Table 3 below recalculates the net present value of costs (in millions of dollars) under different assumptions about two key parameters: the opportunity cost of capital and the value of SO_2 and NO_X reductions (expressed as a multiple of the original assumed values). Positive numbers mean that costs exceed benefits, suggesting that under these conditions the project is truly additional. Negative numbers (shaded in brackets) mean that benefits exceed costs, suggesting that the project is not additional.

TABLE 3: Costs (in US$)

Pollutant cost factor	Discount rate		
	5%	15%	25%
0.0	$2.83	$7.51	$8.53
0.5	($8.51)	$2.18	$5.38
1.0	($19.84)	($3.15)	$2.23
2.0	($42.51)	($13.82)	($4.07)

Source: Chomitz (1998), p. 10.

According to the table, if this project were located in an area where no value was placed on SO_2 and NO_X reductions (cost factor = 0), it would not be undertaken. Even with a very low discount rate, the fuel and maintenance savings would not be sufficient to compensate for the investment costs. On the other hand, a similar project located in an area with very high sensitivity to air pollution (cost factor = 2) would be undertaken even with very high discount rates.

The Netherlands has used two projects in Eastern Europe to simulate the substitution of bus engines. The baseline is the existing fleet of buses (van Ham, 1998).

The Wuppertal Institute simulated baselines for four projects: a coal-fired power plant in China, a solar-thermal hybrid power plant in Morocco, a DSM project in Poland, and a cement plant in the Czech Republic (Luhmann et al., 1997). Generally, baselines for power plants can be derived from the official expansion plans of the respective countries. In the China case, Luhmann et al. defined the baseline situation as that of the major domestic coal-fired power plant with a Westinghouse license. That plant has an efficiency of 40.3%, while the latest German technology, including denitrification, would reach 43%. Therefore, the reduction — the difference between the two — would be rather low. Substituting outdated domestic power stations with an efficiency of less than 5% was not considered an acceptable CDM project, because there is a huge energy demand surplus that would prevent shutting down the old plant. This underscores the rationale of limiting the lifetime of such projects to 15 years.

For the solar-hybrid plant, three baselines were developed on the basis of a coal-fired, an oil-fired, and a gas-fired plant. The last was excluded because of high costs, and the oil-fired plant because it did not correspond to the expansion plans of the Moroccan Government.

The DSM case was compared to the existing coal-fired plant and a new, more efficient one. Indirect effects of DSM (rebound of energy consumption or enhanced technology diffusion) were excluded.

The baseline for the cement plant depends on the market situation, because the emissions of an existing plant will vary according to its mode of operation. In case of the substitution of a plant, the average annual emissions of the existing plant over several years are taken as the baseline. An additional plant will be evaluated in a feasibility study.

PROJECT-SPECIFIC BASELINES WITH SECTORAL ELEMENTS

From the discussion above, it is obvious that project-related baselines can be defined in very different ways. It seems to be impossible — at least at the current stage — to explicitly introduce indirect effects. Moreover, some definitions of baselines clearly preclude projects that offer very effective emission reductions by replacing old, inefficient plants. Therefore, in Appendix 1 to this chapter, a categorisation of projects with specific baselines is introduced (Michaelowa, 1995, pp. 78-82). They are meant to provide a guideline and do not contain engineering detail. The appendix begins with options in the energy supply sector, but also covers efficiency enhancement and reduction in demand as well as sequestration. The crucial issue of the remaining lifetime of replaced installations is covered by a calculation of the commercial lifetime and a "no regrets" cutoff rule of 10 years. Hagler-Bailly (1998a, Chapter 2) has recently come up with similar proposals concerning the baselines for different project categories.

The advantage of categorising projects across countries is that it leaves political considerations outside of the baseline determination. As shown in the Costa Rican example, the decision to phase out fossil fuel for electricity production was penalised by a low baseline for AIJ energy projects. This could lead to the perverse incentive for host country governments to give up responsibility for environmental protection in order to increase the baseline projections.

However, no project category should be excluded in advance. If a project does not fit into the existing categories or claims higher benefits, it should exceptionally be given the opportunity to prove its effectiveness by drawing an individual baseline using conservative assumptions. This baseline would have to be revised on a regular basis.

RECOMMENDATIONS FOR POLITICAL DECISIONS ON THE BASELINE ISSUE

Despite efforts to develop realistic baseline scenarios, a certain degree of uncertainty regarding actual reductions will be inevitable. It is therefore necessary to weigh the costs of developing a baseline against the informational benefit it can be expected to yield. The same applies to the concept of dynamic baselines, which should be investigated further. While project-related baselines are already being used, the proponents of country-related baselines have still to show the applicability of their approach for the CDM. The results from the AIJ pilot projects are patchy and show that project-related baselines can be problematic, especially in countries undergoing rapid change from distorted to deregulated energy markets.

The possibility of quantifying indirect effects and considering market distortions and subsidies through aggregation in the country-related baselines is countered by the malleability and uncertainty of the assumptions required in an aggregate baseline scenario. Given currently available insights, this consideration leads us to recommend project-specific baseline scenarios as a basis for the CDM. In cases of severely distorted markets undergoing liberalisation or subsidy phase-out, a country-related or a sectoral baseline might be more appropriate. Focussing on categorised project baselines can help reduce transaction costs — which have so far not been quantified, but which will become a matter of close scrutiny if the CDM moves forward. In the pilot phase, different approaches for defining project-related baselines should not only be tolerated but also actively encouraged. The experience that can be collected will be indispensable in devising criteria and guidelines for CDM baselines.

APPENDIX 1: BASELINES FOR DIFFERENT PROJECT TYPES

PROJECT 1: Improving Efficiency Levels of Existing Power Stations

Baseline	Emission reduction	Project lifetime	Case in which baseline applies
Efficiency level of plant before improvement	E(old)-E(new)	Commercial life of old plant (approximate value: depreciation period)	Plant still operating economically
Average level of efficiency in new plant (built in the past 5 years)	E(mean)-E(new)	Commercial life of new plant (approximate value: depreciation period)	Commercial life of old plant has run out
Efficiency level of plant before improvement	E(old)-E(new)	10 years	Transitional solution for outdated power stations; to start within 3 years after the CDM mechanism comes into force

PROJECT 2: Replacing Old Power Plant with New Plant Using the Same Fuel

Baseline	Emission reduction	Project lifetime	Case in which baseline applies
Efficiency level of plant before improvement	E(old)-E(new)	Commercial life of old plant (approximate value: depreciation period)	Plant still operating economically
Average level of efficiency in new plant (built in the past 5 years)	E(mean)-E(new)	Commercial life of new plant (approximate value: depreciation period)	Commercial life of old plant has run out
Efficiency level of the old plant	E(old)-E(new)	10 years	Transitional solution for outdated power stations; to start within 3 years after the CDM mechanism comes into force

PROJECT 3: Fuel Substitution, Same Level of Efficiency

Baseline	Emission reduction	Project lifetime	Case in which baseline applies
Fuel actually used previously	E(old)-E(new)	Commercial life of old plant (approximate value: depreciation period)	Plant still operating economically
Average level of efficiency in new plant operating on previous fuel (built in the past 5 years)	E(mean)-E(new)	Commercial life of new plant (approximate value: depreciation period)	Commercial life of old plant has run out; reference is previous fuel, as autonomous fuel substitution cannot be assumed
Fuel actually used previously	E(old)-E(new)	10 years	Transitional solution for outdated power stations; to start within 3 years after the CDM mechanism comes into force

PROJECT 4: Fuel Substitution, Same Level of Efficiency

Baseline	Emission reduction	Project lifetime	Case in which baseline applies
Fuel actually used previously, level of efficiency in old plant	E(old)-E(new)	Commercial life of old plant (approximate value: depreciation period)	Plant still operating economically
Fuel actually used previously, average level of efficiency in new plant operating on previous fuel (built in the past 5 years)	E(mean)-E(new)	Commercial life of new plant (approximate value: depreciation period)	Commercial life of old plant has run out; reference is previous fuel, as autonomous fuel substitution cannot be assumed
Fuel actually used previously	E(old)-E(new)	10 years	Transitional solution for outdated power stations; to start within 3 years after the CDM mechanism comes into force

PROJECT 5: Additional Power Plant

Baseline	Emission reduction	Project lifetime	Case in which baseline applies
Average level of efficiency in new plant operating on same fuel (built in the past 5 years)	E(mean)-E(new)	Commercial life of new plant (approximate value: depreciation period)	Reference fuel used in additional power plant

PROJECT 6: Replacing Old Power Plant with New Plant Using Renewable Energies

Baseline	Emission reduction	Project lifetime	Case in which baseline applies
Efficiency level of plant before improvement	E(old)	Commercial life of old plant (approximate value: depreciation period)	Plant still operating economically
Average level of efficiency in new plant operating on old fuel (built in the past 5 years)	E(mean)	Commercial life of new plant (approximate value: depreciation period)	Commercial life of old plant has run out
Efficiency level of the old plant	E(old)	10 years	Transitional solution for outdated power stations; to start within 3 years after the CDM mechanism comes into force

PROJECT 7: Additional Power Plant Using Renewable Energies

Baseline	Emission reduction	Project lifetime	Comments
Average level of efficiency in new plant operating on fossil fuels (built in the past 5 years), weighting by means of emission factors	E(mean)	Commercial life of new plant (approximate value: depreciation period)	Reference fuel weighted average of fossil fuels

PROJECT 8: Training and Information for the Operators of Existing Power Plants

Baseline	Emission reduction	Project lifetime	Comments
Actual level of efficiency before training	E(old)-E(T_1)	As long as E(T_1) < E(old), regular measurements	Problem: recognising temporary effects

PROJECT 9: Demand-Side Energy Conservation by Improving the Energy Efficiency of Existing Applications

Baseline	Emission reduction	Project lifetime	Reasons, comments
Fossil-fuel energy consumption before investment	E(old)-E(new)	Average commercial life of investment	Problem: Taking behavioural changes into account is difficult; therefore, unchanged behaviour is assumed and the rise in technical efficiency ascertained

PROJECT 10: Demand-Side Energy Conservation by Improving the Energy Efficiency of New Applications

Baseline	Emission reduction	Project lifetime	Reasons, comments
Average fossil-fuel energy consumption of corresponding applications of the past 5 years	E(mean)-E(new)	Average commercial life of investment	

PROJECT 11: Demand-Side Energy Conservation through Behavioural Change

Baseline	Emission reduction	Project lifetime	Reasons, comments
Target-group fossil-fuel energy consumption before influence (average over 3 years)	E(mean)-E(new)	As long as E(new) < E(mean), regular measurement	No numerical change in group size; problem: particular difficulties in determining whether the saving is really a result of the project
Target group fossil-fuel energy consumption before influence (average over 3 years), taking increase into consideration	E(mean)* z(new)/ z(old)- E(new)	As long as : E(new) > E(mean) * z(new)/ z(old)	Numerical change in group size; problem: particular difficulties in determining whether the saving is really a result of the project

PROJECT 12: Greenhouse Gas Sequestration through Changes in Land Use

Baseline	Emission reduction	Project lifetime	Reasons, comments
Storage before change in use	$S(T_1)$-$S(T_0)$	As long as $S(T_1) > S(T_0)$	$S(T_1)$-$S(T_0)$: annual sequestration

E, emission; **S,** storage volume of greenhouse gases; **T_0,** previous period; **T_1,** current period; **z,** size of target group.

Note: The period for crediting is limited, because otherwise the autonomous efficiency improvements are creditable. Replacement of renewable energies by new renewable energies is disregarded, as no emission reduction takes place. If performance is increased, this increase must be treated like an additional generating plant. If no plant has been built in the past 5 years, the last comparable new plant is chosen as a reference standard. Emissions of different greenhouse gases are converted into CO_2 equivalents with the 100-year global warming potentials of IPCC.

REFERENCES

Anderson, R., 1995: Joint Implementation of Climate Change Measures. World Bank Environment Department Papers, Climate Change Series Paper No. 5, Washington, DC.

Andrasko, K., L. Carter, and W. van der Gaast, 1996: Technical Issues in JI Projects. Background paper for the UNEP AIJ Conference, Washington, DC.

Ardone, A., W. Fichtner, M. Wietschel, and O. Rentz, 1996: Analyse von Joint Implementation — Potentialen und Auswahl geeigneter Projekttypen. In: Joint Implementation in Deutschland [Rentz, O., M. Wietschel, W. Fichtner, A. Ardone (eds.)]. Peter Lang, Frankfurt, pp. 49-66.

Bahn, O., A. Cadena, and S. Kypreos, 1998: Joint implementation of CO_2 reduction measures between Switzerland and Colombia (mimeo).

Barrett, S., 1995: The strategy of “Joint Implementation” in the Framework Convention on Climate Change. UNCTAD/GID/10, Geneva.

Bedi, C., 1994: No regrets under Joint Implementation? In: Joint Implementation of Climate Change Commitments [Ghosh, P., and J. Puri (eds.)]. New Delhi, pp. 103-107.

Carter, L., 1997: Modalities for the operationalization of additionality. In: Proceedings of the International AIJ workshop, Leipzig, March 1997 [UNEP, BMU (eds.)], pp. 79-92.

Center for Clean Air Policy, 1998: Top-down baselines to simplify setting of project emission baselines for JI and the CDM. Washington, DC.

Center for Clean Air Policy and SEVEn (eds.), 1996: Joint Implementation projects in Central & Eastern Europe. Prague.

Chomitz, K., 1998: Baselines for greenhouse gas reductions: problems, precedents, solutions. World Bank Carbon Offset Unit, Washington, DC.

Dutschke, M., 1998: Nord-Süd-Kooperation in der Klimapolitik. Zwischen Umwelt und Entwicklung: Joint Implementation am Beispiel Costa Rica. Freiburg i. Br.

Dutschke, M., and A. Michaelowa, 1997: Joint Implementation as Development Policy — The Case of Costa Rica. Hamburg.

Face Foundation, 1995: Face Foundation in Practice. Arnhem, the Netherlands.

Face Foundation, 1996: Annual Report 1995. Arnhem, the Netherlands.

Hagler-Bailly (ed.), 1998a: Evaluating greenhouse gas mitigation through DSM projects: Lessons learned from DSM evaluation in the United States. Boulder, Colorado.

Hagler-Bailly (ed.), 1998b: Evaluation of using benchmarks to satisfy the additionality criterion for Joint Implementation projects. Boulder, Colorado.

Hamwey, R., 1997: A Sustainable Framework for Joint Implementation. IAE Working Paper 51, Geneva.

Heister, J., and F. Stähler, 1994: Globale Umweltpolitik und Joint Implementation: Eine ökonomische Analyse für die Volksrepublik China. Kieler Arbeitspapier No. 644. Kiel, Germany.

Heller, T., 1998: Additionality, transactional barriers and the political economy of climate change. Fondazione Eni Enrico Mattei Nota di lavoro 10.98, Venice, 1998.

Houghton, J., B. Callander, and S. Varney (eds.), 1992: Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment. Cambridge University Press, Cambridge, England.

ICF, Inc., 1997: Additionality: The USIJI Experience. Washington, DC.

Intergovernmental Panel on Climate Change, 1996: Climate Change, 1995: The Economic and Social Dimensions of Climate Change. Cambridge University Press, Cambridge, England.

International Energy Agency, 1997: Activities Implemented Jointly — Partnerships for Climate and Development. Paris.

Jepma, C. (ed.), 1995: The Feasibility of Joint Implementation. Kluwer, Dordrecht, the Netherlands.

Jochem, E., H. Herz, and W. Mannsbart, 1994: Analyse und Diskussion der jüngsten Energiebedarfsprognosen für die großen Industrienationen im Hinblick auf die Vermeidung von Treibhausgasen. Bonn.

Luhmann, H.-J., C. Beuermann, M. Fischedick, and H. Ott, 1995: Making Joint Implementation Operational. Wuppertal Paper No. 31, Wuppertal, Germany, 1995.

Luhmann, H.-J., H. Ott, C. Beuermann, M. Fischedick, P. Hennicke, and L. Bakker, 1997: Joint Implementation — Projektsimulation und Organisation: Operationalisierung eines neuen Instruments der internationalen Klimapolitik. Berlin.

Michaelowa, A., 1995: Joint Implementation of greenhouse gas reductions under consideration of fiscal and regulatory incentives. HWWA Report No. 153, Hamburg, Germany.

Michaelowa, A., 1996: Incentive aspects of Joint Implementation of greenhouse gas reduction. In: Mitigation and Adaptation Strategies for Global Change, vol. 1, No. 1, pp. 95-108.

Michaelowa, A., and S. Greiner, 1996: Interessengruppen und Joint Implementation — Konsequenzen für die Ausgestaltung des Systems. In: Joint Implementation in Deutschland [Rentz, O., M. Wietschel, W. Fichtner, and A. Ardone (eds.)]. Peter Lang, Frankfurt, Germany.

Nordic Council of Ministers (eds.), 1996: Joint Implementation of commitments to mitigate climate change. Copenhagen.

Parkinson, S., K. Begg, P. Bailey, and T. Jackson, 1998: Accounting and accreditation of "Activities Implemented Jointly" under the U.N. Framework Convention on Climate

Change. Paper presented at the ESEE conference, March, Geneva.

Pearce, D., 1995: Joint Implementation: a general overview. In: The Feasibility of Joint Implementation [Jepma, C. (ed.)]. Kluwer, Dordrecht, the Netherlands, pp. 15-31.

Rentz, H., 1998: Joint Implementation and the question of additionality — a proposal for a pragmatic approach to identify possible Joint Implementation projects. Energy Policy, **4,** 275-279.

Rentz, O., M. Wietschel, A. Ardone, W. Fichtner, and M. Göbelt, 1998: Zur Effizienz einer länderübergreifenden Zusammenarbeit bei der Klimavorsorge. Karlsruhe, Germany, 1998.

Roland, K. and T. Haugland, 1995: Joint Implementation: difficult to implement? In: The Feasibility of Joint Implementation [Jepma, C. (ed.)]. Kluwer, Dordrecht, the Netherlands, pp. 359-366.

SGS, 1998: Protected Areas Project. Costa Rican Office for Joint Implementation: Final Report. Oxford University Press, Oxford, England.

Sutherland, R., 1996: The economics of energy conservation policy. Energy Policy, **4,** 361-370.

Torvanger, A., J. Fuglestvedt, C. Hagem, L. Ringius, R. Selrod, and H. Aaheim, 1994: Joint Implementation under the Climate Convention: Phases, Options and Incentives. CICERO Report 1994:6, Oslo.

UN Framework Convention on Climate Change, 1997: Activities Implemented Jointly under the Pilot Phase. FCCC/SBSTA/1997/INF.3, Bonn.

US Initiative on Joint Implementation, 1996: Activities implemented jointly: first report to the secretariat of the United Nations Framework Convention on Climate Change, submitted by the Government of the United States, July, Washington, DC.

van der Burg, T., 1994: Economic aspects. In: Joint Implementation to Curb Climate Change [Kuik, O., P. Peters, and N. Schrijver (eds.)]. Kluwer, Dordrecht, the Netherlands, pp. 73-126.

van Ham, J., 1998: Methodology for baseline and credit-sharing: the RABA/IKARUS compressed natural gas engine for buses. In: Greenhouse Gas Mitigation [Riemer, P., A. Smith, and K. Thambimuthu (eds.)]. Technologies for Activities Implemented Jointly, Amsterdam, pp. 617-622.

Wirl, F., C. Huber, and I. Walker, 1996: Joint Implementation: Strategic Reaction and Possible Remedies. Preprint Fakultät für Wirtschaftswissenschaften 9, Magdeburg, Germany.

CHAPTER 9

Understanding additionality[1]

Kevin A. Baumert
World Resources Institute
Washington, DC

SUMMARY: This chapter examines the question of additionality, which is dealt with in Article 12.5 of the Kyoto Protocol in the context of defining the Clean Development Mechanism (CDM). The Protocol requires that emission reductions certified under the CDM be "additional" to what would have occurred in the absence of project activities. This chapter treats the two main components of the criterion — financial and environmental additionality. No specific recommendations are made, but implications of various ways of applying additionality — some of them quite controversial — are explored. The first section explains the importance of additionality and establishes conceptual definitions for financial and environmental additionality. The second section treats the range of definitions and interpretations of financial additionality, and the third explains baseline construction methods that have been put forth to measure environmental additionality. These can be divided into two categories: "top-down" baselines, derived from aggregate national or sectoral emissions data, and "bottom-up" baselines, derived from specific projects.

WHAT IS ADDITIONALITY AND WHY IS IT IMPORTANT?

The Kyoto Protocol created a suite of "flexibility mechanisms." In addition to the Clean Development Mechanism (CDM), an instrument for co-operation between developed (Annex I) countries and developing (non–Annex I) countries, the flexibility mechanisms include international emissions trading (Article 17), Joint Implementation between Annex I countries (JI, Article 6), and bubbles (Article 4). More than the other mechanisms, the CDM has the potential to reward projects that do not limit emissions, or that would have been undertaken anyway. To guard against this possibility, Article 12.5 of the Kyoto Protocol stipulates that greenhouse gas reductions that take place under this mechanism

---

[1] *This chapter was originally produced as part of the Clean Development Mechanism Design Project, a collaborative effort of the World Resources Institute, the Center for Sustainable Development in the Americas (CSDA), and the Foundation for International Environmental Law (FIELD). See the Clean Development Mechanism: Draft Working Papers, October 1998. WRI, CSDA, and FIELD.*

must be "*additional* to any that would otherwise occur in the absence of the certified project activity" (emphasis added). This criterion, coupled with other United Nations Framework Convention on Climate Change language,[2] has given birth to a broad range of definitions and assumptions about additionality and its implications.

Financial additionality.[3] Financial additionality refers to whether project investment would have taken place in the absence of the credit-gaining CDM provisions. According to some interpretations of Article 12.5(c), projects that would have taken place anyway — "anyway" projects — are not eligible for certified emission reductions (CERs)[4] under the CDM.

The example below illustrates one way of conceptualising financial additionality:

For Solar Company to undertake a solar installation project in a developing country, an expected rate of return of 15% is needed. Without crediting, the expected rate of return is 10%, and the project will not be undertaken. However, under the credit-granting CDM, the rate of return is 20 percent (because of the asset value of the credits), and Solar Company will implement the project. *This project is financially additional.* Alternatively, however, if the return on the investment without credits were 15%, then the project would not be financially additional because it would have taken place without the CDM.

Although specific definitions have been put forth, there is no universally recognised definition of financial additionality. But what is important is how (or whether) to apply the concept of financial additionality, embodied in Article 12.5(c), and avoid credits from being generated from "anyway" projects.

Environmental additionality.[5] Environmental additionality refers both to Article 12.5(c), cited above, and Article 12.5(b): "Emission reductions resulting from each project activity shall be certified ... on the basis of ... *real, measurable,* and long-term benefits related to the mitigation of climate change" (emphasis added). Unlike financial additionality, which is usually expressed *categorically* (in the form of "yes," meaning that a project is financially additional, or "no," meaning that it is not), environmental additionality can be measured and is expressed *quantitatively* to satisfy the "real, measurable" component of Article 12.5(b). For example, Solar Company must now calculate the overall amount of greenhouse gases (GHGs) abated by the project relative to a baseline. This calculation is the quantitative basis for obtaining CER credits, and non-environmentally additional projects can in no way earn credits through CDM project activities. Determining environmental additionality requires:

1. a project *baseline*, or reference case, that estimates what would have happened in the absence of the CDM project
2. methods for estimating a project's actual GHG emissions or sequestration
3. a quantitative comparison of actual emissions to baseline projections. The difference between the baseline and actual emissions (the amount of GHGs abated) is the amount of environmental additionality achieved by the project.

Thus, environmental additionality answers the question, "How many CERs should a project generate?" Alternatively, "What quantity of GHGs was abated by the project?" As with financial additionality, there is no common and widely accepted method for measuring GHG reductions.

Significance of the additionality debate. The primary importance of the additionality debate is ensuring the environmental integrity of the Kyoto Protocol. Including business-as-usual (non-financially additional) projects in the CDM will increase global GHG emissions.[6] The same is true if lax methods prevent an accurate quantification of environmental additionality — "overcrediting" projects from developing countries will introduce "paper tons" into an international

---

[2] *Such as COP Decision 5/CP.1, establishing the Activities Implemented Jointly pilot phase.*

[3] *Alternatively referred to as "project additionality."*

[4] *CERs are also often referred to as "CDM credits" or certified emission reduction units (CERUs).*

[5] *Alternatively referred to as "emissions additionality." See Carter (1997) on USIJI and Rolfe (1998).*

[6] *Credits generated from non-financially additional projects would be added to the assigned amount of the investing country, enabling that country to emit more domestically without the project's CDM generating* real *offsets.*

emissions trading system. In contrast, overstringent definitions of additionality will discourage project implementation and exclude legitimate GHG-reducing projects. Thus, it has been correctly suggested that trade-offs are needed; the costs of measuring additionality (which affect incentives, administrative ease, and so on) must be weighed against the accuracy of the measurements.

Moreover, additionality is a key component of CDM project *eligibility.* Article 12.5 specifies the basis upon which such emission reductions shall be certified (what is eligible). Sections b and c of Article 12.5, as discussed above, address additionality.[7] Thus, project eligibility is a function of how the additionality criteria are applied. Projects that are CDM-eligible could be defined in terms of environmental additionality only, environmental and financial additionality, specific categories of projects that are *a priori* eligible, sustainable development benefits, or a combination of these and other criteria. Regardless, additionality will play a key role in some fashion because *all* CDM activities must be environmentally additional.

Third, common definitions are needed before projects can be credited. In the Activities Implemented Jointly (AIJ) pilot phase, determining financial and environmental additionality occurs at the national level under the jurisdiction of AIJ programs (for example, USIJI in the United States and JPAIJ in Japan). This has led to a proliferation of methods and definitions. Because of the asset value of certified emission reductions, a mature crediting CDM regime will require consistent application of the additionality criteria and methods by all parties. The early crediting/banking provision in Article 12.10 (credits may be obtained beginning in 2000) makes this particularly pressing for the CDM.

FINANCIAL ADDITIONALITY

Referring to additionality, a USIJI report to the UNFCCC Secretariat states that "in practice this has been a particularly difficult criteria to *apply*" (Carter, 1997; emphasis added). The hypothetical nature of additionality, definitional confusion, and the need to determine the *intent* of the investor are components of the challenge of applying financial additionality.[8] This is further complicated by "no regrets" projects or other "profitable" ventures that have both environmental and economic benefits.[9] Coal-to-gas fuel-switching projects, for example, may lower GHG emissions *and* are often economically rational. Such projects would probably not pass a strict financial additionality test because they would be undertaken by the host country or a foreign investor in the absence of the credit-granting CDM.

There are several problems, however, with an approach that excludes projects with both economic and environmental (in terms of GHG reductions) benefits. Foremost among them is the fact that there are no guarantees that "no regrets" projects will in fact be undertaken. Many argue that failure to undertake such projects is at the heart of the climate problem. The US Environmental Protection Agency's voluntary industry outreach programs (such as Energy Star, Green Lights, and Climate Wise) aim to overcome non-price barriers (such as lack of information, uncertainty over future conditions, and risk aversion) that prevent "no regrets" measures from being executed.

Recognising the challenges posed by hypothetical baseline scenarios, multiple definitions, and unexploited "no regrets" projects, several options for applying financial additionality and Article 12.5(c) include:[10]

1. *Accept all projects financed outside of Official Development Assistance (ODA) and the Global*

---

[7] *12.5(a) stipulates that participation in CDM activities is voluntary. Borrowed from the AIJ pilot phase, this is an uncontroversial eligibility requirement for all projects.*

[8] *The USIJI Evaluation Panel adds that there is "difficulty in seeking to gauge* why *participants might undertake projects or specific measures, since most projects will be done for multiple reasons." USIJI, 1994; emphasis added.*

[9] *See Chomitz (1998) and Carter (1997) on the IPCC.*

[10] *Generally, Options 1-3 are "categorical" and thus easy to determine. Options 4-6 must be determined on a project-by-project basis.*

Environment Fund (GEF) as financially additional. This approach, taken by USIJI, would be simple to administer and is most consistent with COP decision 5/CP.1, which established the AIJ Pilot Phase.[11] Under it, USAID-related projects, for example, would be excluded from CDM crediting. North-South equity issues drive this component of the financial additionality debate, because the CDM could re-orient ODA or GEF flows towards GHG reduction projects, at the expense of pursuing other important development goals. CDM flows, it is often argued, should create a *new* source of private development funding, rather than take place at the expense of existing development assistance programs. A variation of this option, which would yield similar results in practise, is to *accept any project financed by the private sector as financially additional.* This would also enable some government-funded CDM projects to be eligible, if it was adequately demonstrated that ODA funding was new and additional, as the Swiss AIJ programs shows.[12] The World Bank notes that "private sector investment [in AIJ] is generally recognised as inherently additional."[13]

2. *Accept any project initiated by the host country as financially additional.* This guideline would enable developing countries to implement their own project or portfolio of projects and generate CERs to market through the CDM. Perhaps it can be reasonably assured that CDM projects proposed by hosts that are eventually financed by Annex I entities "would not have taken place otherwise" and are therefore financially additional.

3. *Accept any project included in categories that are* a priori *considered financially additional.* Like several other approaches, categorisation of projects would be extremely easy to administer. All renewable energy projects, for example, could be considered automatically additional, for an agreed-upon period of time. This approach promotes projects that are likely to embody positive externalities and helps overcome investment barriers for non-carbon technologies (Michaelowa and Dutschke, 1998). The viability of this approach depends almost completely on the selection of categories.

4. *Accept any project that demonstrates, through financial analysis, that the project would not have taken place "but for" CERs.* CERs represent a potential asset stream from project activities that can boost the return on investment. Requiring a demonstration that CERs enable the project to be implemented is a rigorous guideline, but also the most consistent with the financial additionality example illustrated in the first section. Several challenges posed by this criterion include the unknown future value of CERs, the potential for manipulation of financial analysis, and high transaction costs.

5. *Accept any project that demonstrates that the project overcomes "barriers" to implementation.* CDM projects that overcome market failures or institutional, technological, or other barriers would be considered financially additional. Overcoming barriers to implementation, such as lack of information and risk aversion, is precisely the rationale for government programs that promote "no regrets" action and is also a component of the USIJI additionality criteria.[14] Evaluation of the barrier(s) identified by project developers, conducted by the CDM Executive Board or another body, would be required to ensure that they are indeed real. The "barrier removal method," advanced by the International Energy Agency could serve as a model (IEA, 1997).

6. *Accept any project that demonstrates "programme additionality."* Borrowed from USIJI, this option stipulates that project developers may demonstrate that the investment is being

---

[11] *COP Decision 5/CP.1, which established the AIJ pilot phase in 1995, states that "the financing of activities implemented jointly shall be additional to the financial obligations of Parties included in Annex II to the Convention within the framework of the financial mechanism as well as to current official development assistance (ODA) flows." On this subject, Carter (1997) defines financial additionality as being in addition to normal ODA. See also Sokona et al. (1998), USIJI (1994), World Bank (1995), and Yamin (1998).*

[12] *SWAPP (1998). COP Decision 5/CP.1 does not categorically deny ODA projects for AIJ, but stipulates that they be "additional to ... current official development assistance flows." This suggests an "ODA baseline."*

[13] *World Bank (1995). See also Yamin (1998).*

[14] *USIJI (1994) and Carter (1997).*

initiated directly as a result of the CDM, or in reasonable anticipation of the CDM.[15] Project proponents can demonstrate this by documenting that the project was initiated specifically for the CDM in response to workshops, host outreach efforts, or consultations.

7. *No financial additionality criteria.* Some have suggested that only an environmental additionality test is desirable and that financial additionality "adds transaction costs without enhancing environmental performance."[16] According to this argument, actual project emissions, assessed in relation to baselines, should be the only criterion for assessing additionality. In many cases, financial additionality arguments may be a vestige of AIJ programs, which do not involve crediting and thus do not require rigorous environmental additionality measurements. Dropping the financial additionality requirement would need to be complemented by rigorous bottom-up baseline determination methods (see below) that capture business-as-usual scenarios and ensure that "anyway" projects are not credited.

A combination of the above approaches could also serve as a basis for determining financial additionality. For example, some criteria could be established as necessary, but not sufficient, for demonstrating financial additionality. Others could be deemed sufficient.

ENVIRONMENTAL ADDITIONALITY AND BASELINES

Because CERs are potentially valuable assets, useful in demonstrating domestic or international regulatory compliance, the subject of accurately quantifying GHG reductions is particularly important. Determining environmental additionality requires a quantitative comparison of actual project emissions to baseline projections. The most crucial component to determining environmental additionality is the project *baseline*, which defines the scenario that "would have taken place" in the absence of the CDM project.[17] Several approaches, which are summarised below, have been put forth as possible methods for determining the baseline of a project. For simplicity, these methods are categorised into two general approaches — those derived from aggregate data, or "top-down" baselines, and those determined case-by-case, or "bottom-up" baselines. Within each approach, baselines can be historical or forward-looking, dynamic or static, or rate- or ton-based.

Top-Down Baselines

Top-down baselines typically derive an "emission rate" from existing national or sectoral data or establish a "cap" on company, sector, or national emission levels. Examples of top-down baselines, which often use precise metrics to capture the GHG -intensity of a country or sector, include:

- GHG emissions/megawatt hour (using national energy production data)
- GHG emissions/average mileage (using national transportation sector data)
- GHG emissions/dollar cost of output (using sector or company data)
- GHG emissions/unit of output (using sector or company data)
- Total emissions in the energy generation sector (using absolute emission projections)

To determine a project's actual emission reductions (its environmental additionality) during a given period, the *national/sectoral* emission rate (such as kg C/MWh) is compared to the actual *project* emission rate (kg C/MWh). The difference between the two rates, in terms of actual tons of GHG emissions, is the quantitative basis for determining CERs. Most proponents of this approach believe that baselines should remain fixed over the lifetime of the project. However, the

---

[15] *Carter (1997) and USIJI (1994).*

[16] *EDF (1998). See also Carter (1997) and CCAP (1998).*

[17] *The other necessary component in measuring environmental additionality, not addressed here, is estimating the actual emissions, or the emissions rate, of a project. In some cases, project emissions are simple to measure, such as a solar energy project that has zero emissions or large stationary sources. In other cases, measurement of direct and indirect emissions (leakage) is extremely difficult. Environmental additionality issues related to land-use change and forestry (LUCF) are not treated here.*

national/sectoral emission rates can be recalculated on a yearly basis for new CDM projects coming on line (Hamwey and Szekely, 1998).

Historical top-down baselines. Some proponents of "top-down" baselines argue that "previous and existing sectoral activities in any national setting, implemented largely in the absence of climate change considerations, provide the best gauge of what future activities would take place in near-term national [business-as-usual] scenarios."[18] Thus, historically based "top-down" baselines use current or past national/sectoral data to determine the appropriate emission rate.

One detailed proposal, by Hamwey and Szekely (1998), uses this approach for determining baselines in the energy sector. This "observable baseline framework" uses a *national emissions factor,* which is calculated by dividing total annual CO_2 emissions by the total energy generated in this sector (kg C/MWh). To ensure that projects well above the average are undertaken (and to avoid possible technology "dumping"), the national emissions factor (baseline) could be calculated by including only the top tier of efficient facilities (Hamwey and Szekely, 1998).

Forward-looking top-down baselines. Similar rates can also be derived by projecting national and sectoral trends. For example, forecasting emission rates in the energy sector, using already planned technologies, would be one means of more accurately accounting for future change. Another example of this kind of baseline is a national emission reduction or limitation commitment, expressed in tons of carbon equivalent. Project baselines could be apportioned from such a quantitative national cap.

Advantages of "top-down" approaches include low transaction costs, potentially larger investment flows, easy comparison, and "GHG growth potential" for developing countries.

- Transaction costs for investors are low because baselines for an entire country or sector are pre-determined annually by national governments and/or UNFCCC bodies. Investors do not need to undertake detailed and expensive studies to determine a project's baseline. Similarly, regulators do not need to undertake a case-by-case approval process (CCAP, 1998). In addition, this approach is quantitatively precise and the calculations are relatively simple.
- Top-down approaches reduce leakage potential and indirect effects of CDM projects. The emissions implications of a sector-wide energy price increase, for example, would be better accounted for in a system that covered total sectoral emissions.
- Because of the low transaction costs and lack of administrative burden, greater CDM flows could be generated.
- "Emission rates" are easy to compare across sectors and countries to determine where the greatest potential exists for CDM projects. This comparability, using metrics that express carbon intensity, will dynamically promote investment toward the most inefficient countries and sectors (Hamwey and Szekely, 1998).
- The least developed countries should find top-down baselines appealing because they are not based strictly on emission *reductions.* Some countries do not have plentiful emission reduction opportunities simply because actual emission levels are extremely low — in most cases, orders of magnitude lower than those of transitional and industrialised countries. Table 1 illustrates the tremendous emissions disparities in non–Annex I countries. Top-down baselines allow CERs to include "avoided future emissions"

TABLE 1:[19] CO_2 Emissions, Selected Non-Annex I Countries, 1995

Country	('000 tons)
China	3,192,484
India	908,734
Mexico	357,834
Kenya	6683
Nepal	1532
Uganda	1044

---

[18] *Hamwey (1998). See also CCAP (1998).*

[19] *Figures represent CO_2 emissions from fossil fuel burning and cement manufacturing (WRR, 1998).*

as well as true emission reductions, helping to ensure that the least developed countries are not overlooked by CDM investors, as they have been in the AIJ pilot phase (Sokona et al., 1998).

Drawbacks of this approach include comprehensive data requirements, poor host country investment incentives, and the possible expectation of developing country emission reduction commitments.

- Measurement requirements are high under most top-down systems. The costs of developing the capacity to accurately measure emissions in all relevant countries and sectors would be significant. Countries would need to establish comprehensive measuring and monitoring programmes for their national and/or sectoral emissions. The difficulty in gathering the requisite data would vary greatly across countries.
- A top-down, rate-based approach would allow developing countries to increase overall GHG emission levels. Would this qualify as a "real" reduction? Many believe it would not, even when compared with "real" increases in GHG emissions under business-as-usual scenarios in developing countries. One danger in allowing CERs to be based on "avoided future emissions" is that it will enable Annex I countries to emit more domestically. This approach would allow the largest flow of CERs, which would, in turn, allow Annex I Parties significantly higher levels of domestic emissions.
- Historical approaches such as the "observable baseline framework" do not capture marginal decisions, which are crucial in determining "what would otherwise have happened." For example, a country's energy sector could be predominantly coal-oriented, yet this does not mean that the next plant built will also be coal-powered. Marginal increases in energy generation capacity may include lower carbon options, such as combined-cycle gas turbines, even under a business-as-usual projection. The historical approach also ignores regional considerations because all sectoral sources — regardless of location — are subject to the same baseline.
- Host countries will have incentives to keep emission rates as high as possible for the purpose of attracting investment. Thus, there is an incentive for high-carbon domestic investments (which will keep national/sectoral emission rates high) and for overstating domestic emissions. Domestic mitigation incentives could be created by ensuring that hosts can also implement projects and market CERs through the CDM.
- The easiest way to formulate top-down baselines is to derive them from an overall GHG limitation or reduction target (rather than measured data). Because of possible links to voluntary or binding commitments, many developing countries may be reluctant to advocate this approach.

Bottom-Up Baselines[20]

The key conceptual difference between top-down and bottom-up baselines is that the latter are determined on a case-by-case basis. While top-down approaches use aggregated national or sectoral data, as described above, bottom-up approaches use a specific technology or reference case for comparison. Bottom-up baselines do not require large amounts of national or sectoral data to formulate a baseline. A project baseline of this kind may take the form of a benchmark emission rate, or it may be a measureable amount — for instance, tons of carbon equivalent.

As with all baselines, determining environmental additionality requires a comparison between the project baseline and the actual project emissions. For example, a fuel-switching or efficiency improvement project would use the emission rate of the old plant (kg carbon/MWh) as the baseline. Comparing this figure to the emission rate of the new facility would allow for calculation of the amount of GHGs abated. Similarly, the actual or projected emission level of the old plant (measured in tons) could be the basis for determining the baseline. The overriding baseline challenges are determining *what* technologies to benchmark and estimating when technologies will shift (Chomitz, 1998).

Options for bottom-up baselines include:

Historical bottom-up baselines. Like "observable baselines," historical benchmarks look to the past as an indicator for what will likely happen in the future. New projects may have a very clear

---

[20] *Variations of bottom-up baselines include "technological benchmarking" and "reference cases."*

reference case or comparison group, representing "present practise," from which to compare emission scenarios and determine environmental additionality. For example, a demand-side management project that switches to more energy-efficient lighting practises can be compared to the currently installed system. The resulting difference in energy saved could be converted into tons of carbon. The strengths of this method include its ease of use and straightforward basis of comparison. However, it may not be applicable to many non-technology-based projects or programmes, and is a static model that may become quickly outdated. One way to deal with this problem is to gradually "deflate" the baseline over time.

Forward-looking, bottom-up baselines. Other benchmarks rely on energy or technology forecasts in developing countries. This may help overcome the static shortcomings of historical reference cases and capture the marginal decisions that affect GHG emissions. For example, if new coal-fired power plants are already planned in a developing country, they could serve as the baseline for less carbon-intensive power generation projects implemented through the CDM. Alternatively, forward-looking benchmarks could be based on the "best planned technology" or projected emissions for a process or source. To try to capture business-as-usual efficiency improvements, benchmark rates or emission levels can decline over time, until projects eventually fail to earn additional CERs. Drawbacks include a lack of reliable or credible forecast data.

Baseline Mitigation Measures

Project baselines are by definition hypothetical. They will never happen, and conclusive answers will never be gleaned from baseline projections. Recognizing that differing assumptions will invariably yield differing outcomes of baseline estimations, proposals have also been put forth that attempt to mitigate the uncertainty, rather than tackle it directly as the above-mentioned methods attempt. Mitigation strategies, which could be used in concert with estimation techniques discussed above, include:

Offsets averaging. This approach pools projects for certification of emission reductions. The hope is that inaccurate environmental additionality estimations of individual projects will be balanced by other projects that overestimate reductions. By certifying projects collectively, the risk of overcrediting individual projects is minimised. Offsets averaging is consistent with the World Bank's Prototype Carbon Fund, portfolios of projects developed by individual investors, and the host-driven portfolio approach to the CDM.[21]

Discounting. Projects that are "discounted" are granted only partial credit for certified GHG reductions. Discounting may take place at the project level, sector level (for instance, all land-use change projects), or system level (all CDM projects). Reasons for discounting credits include:

- Uncertainties in baseline estimations or uncertain project emission measurements. Projects in sectors with difficult-to-measure emissions, as well as leakage-prone or policy-oriented "projects" (such as carbon taxes), may be discounted for this reason. For example, impermanence of forest sector reductions could be subject to sector-level discounting.
- Intertemporal uncertainty.[22] Progressively higher discount rates over time may be desirable for many projects because of increasing baseline uncertainty. For example, baseline estimation will be more accurate during the early years of a project than 30 years in the future. Discounting over time will help account for shifts in technology or procedures that are expected to take place at some unknown future date. This is one means of making baselines dynamic over time and is an alternative to "deflating" emission rates, discussed above.
- "Supplementarity" purposes. Discounting may be a means of ensuring that overseas domestic greenhouse gas reductions are balanced by domestic action, as specified in Article 12.[23]

---

[21] *Costa Rica's Certifiable Tradable Offsets programme is an excellent example of a host-driven portfolio approach. See Yamin (1998).*

[22] *Michaelowa and Dutschke (1998).*

[23] *Article 12.3(b) states that Annex I Parties may achieve "part" of their commitments through CDM-generated credits. See Begg et al. (1998) and Michaelowa and Dutschke (1998).*

Limiting project lifetimes. Similar in intent to intertemporal discounting, this measure establishes a concrete limit to the length of time that a project may earn CERs.

Limiting project eligibility. Projects or programmes with particularly difficult emission or baseline estimations could be rendered CDM ineligible. This is compatible with the option of "categorising" projects that are a priori financially additional (or eligible), as discussed in the previous section.

Voluntary GHG targets for host countries. Establishing emission limitations (concrete assigned amounts) for non–Annex I countries would greatly alter the significance of environmental additionality. Host country targets would transform the CDM into a mechanism similar to Article 6-JI, which involves only countries with binding emission limitation commitments. Here, emission reductions are a "zero-sum" game — GHG reductions from a project are added to the assigned amount of the investor country and subtracted from the assigned amount of the host country.[24] The amount of GHG emission credits generated by a project does not alter the global allowable amount of emissions.[25] Some have advocated this approach precisely because it prevents domestic or international leakage and adds to the environmental integrity of the CDM. Environmentally speaking, measuring GHG reductions would become of secondary importance, and any method could be used, *provided it is agreed upon by all Parties involved.* This would be consistent with resurrecting the "lost Article 10," which dealt with "voluntary commitments" of developing countries and could also be a stepping-stone for emissions trading between Annex I and non–Annex I countries.[26]

Baseline Measurement Units: Rates or Tons?

The units chosen to express baseline estimations could have implications for CDM crediting. Generally, baselines can be expressed in amounts or rates — for instance, in units of carbon equivalent (*tons*) or emission *rates* (tons/MWh). A ton-based system might prevent crediting from taking place while developing countries are rapidly increasing GHG emission levels because the focus is on *verified actual emission reductions.* The rate-based approach, as discussed above, allows for the possibility that CERs may be generated from "avoided future emissions." Although not intended to be quantitatively precise, Table 2 is indicative of different outcomes that can be expected from baselines that are rate-based or ton-based.

TABLE 2: Rates or Tons? Two Scenarios for a 5 Unit of Carbon/MWh Plant

Measurement unit	Baseline	Scenario 1	Scenario 2
Rates: Units of carbon/MWh	10 units/ MWh (100 MWh)	100 MWh used **Result:** 500 CERs (1000-500)	200 MWh used **Result:** 1000 CERs (2000-1000)
Tons: Units of carbon*	1000 units (100 MWh)	500 units emitted **Result:** 500 CERs (1000-500)	1000 units emitted **Result:** 0 CERs (1000-1000)

This example illustrates a simple retro-fit or fuel substitution CDM project. The **baseline** (the "reference case") plant generates 10 units of carbon per MWh. The baseline can be expressed either as this rate of emissions during the reference year (10 units/MWh) or as *total emissions* during the reference year (1000 units of carbon). **The CDM project** generates 5 units of carbon per MWh of operation, a clear improvement over the baseline. Scenario 1 results in 500 CERs, regardless of how the baseline is measured. However, Scenario 2 (unanticipated increase in capacity) results in 1000 CERs and zero CERs for the rate- and ton-based approaches, respectively.
*The amount of actual carbon emissions is a function of the carbon-intensity of the fuel, plant efficiency and capacity (a 1000 MW plant, for instance, may operate at 75% capacity).

---

[24] *The assigned amount mechanics for CDM, Joint Implementation, and emissions trading activities are outlined in Article 3.10, 11, and 12.*

[25] *Situations that involve non-compliance, however, would be an exception to this apparent mathematical certainty. Emissions reduction units generated from Joint Implementation activities may need to be "invalidated" if the host country is not in compliance.*

[26] *See Yamin (1998) and Hamwey and Szekely (1998).*

SUMMARY AND CONCLUSIONS

It is important to distinguish between financial and environmental additionality, two closely related but distinct issues. A high degree of definitional confusion is associated with financial additionality: within the additionality debate, financial additionality is often not defined or not distinguished from environmental additionality.[27] Alternatively, it is often defined only in the following terms: "non-ODA and non-GEF projects are financially additional." The second section of this chapter outlines seven possible options for applying the financial additionality criterion. The strongest options are those that do not entail high transaction costs, but do define clear categories of projects that are financially additional.

The definition of environmental additionality, on the other hand, is straightforward and simple. However, this criterion poses other challenges, namely in developing methodological approaches to accurately and consistently compute environmental additionality. Critical to this calculation is the baseline, which can be derived using "top-down" or "bottom-up" methods, as discussed in the third section. Alternatively, the approaches could be combined in a way that maximizes the comparative strengths of each. Using a combination of top-down and bottom-up approaches for various sectors and project types — with appropriate mitigation measures (such as discounting or offsets averaging) for projects that are particularly prone to leakage, baseline uncertainty, shifting technologies, or negative externalities — may be the most desirable approach.

REFERENCES

Begg, K., and T. Jackson, May 1998: Accounting and Accreditation of Activities Implemented Jointly (A3IJ). 2nd Interim Report, Summary Report, Center for Environmental Strategy, University of Surrey.

Begg, K., S. Parkinson, P. Bailey, and T. Jackson, March 4-7, 1998: Accounting and Accreditation of "Activities Implemented Jointly" under the UN Framework Convention on Climate Change. Center for Environmental Strategy, University of Surrey. Presented at the Second International Conference of the European Society for Ecological Economics, Geneva.

Brown, P., N. Kete, and R. Livernash, 1998: Forests and land use. In: Issues & Options: The Clean Development Mechanism. United Nations Development Programme.

Carter, L., March 5-6, 1997: Modalities for the Operationalization of Additionality. US EPA/OPPE, presented to UNEP/BMU. Available from http://www.northsea.nl/Jiq/paper.htm.

Center for Clean Air Policy (CCAP), June 1998: Top-Down Baselines to Simplify Setting of Project Emission Baselines for JI and the CDM: Simplifying JI and CDM Baseline Rules without Compromising Environmental Effectiveness.

Chomitz, K., May 22, 1998: Baselines for Greenhouse Gas Reductions: Problems, Precedents, Solutions. Development Research Group, World Bank (prepared for the Carbon Offsets Unit).

Environmental Defense Fund (EDF), June 1998: Cooperative Mechanisms Under the Kyoto Protocol: The Path Forward.

Hamwey, R., 1998: A sustainable framework for joint implementation. International Environmental Affairs **10** (No. 2).

Hamwey, R., and F. Szekely, 1998: Practical approaches in the energy sector. In: Issues & Options: The Clean Development Mechanism. United Nations Development Programme.

Hassing, P., and M.S. Mendis, May 13, 1998: The Clean Development Mechanism as an instrument for sustainable development: issues

---

[27] *Partly because much of the literature is in an AIJ context, where precise measurements of environmental additionality are not needed because there is no crediting.*

and options. In: Issues & Options: The Clean Development Mechanism. United Nations Development Programme.

Intergovernmental Panel on Climate Change, 1996: Climate Change, 1995: Economic and Social Dimensions of Climate Change. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change [Bruce, J.P., H. Lee, and E.F. Haites (eds.)]. Cambridge University Press, Cambridge, England.

International Energy Agency (IEA), 1997: Activities Implemented Jointly: Partnerships for Climate and Development. Energy and Environment Policy Analysis Series. IEA/OECD.

Michaelowa, A., and M. Dutschke, May 28-29, 1998: Creation and sharing of credits through the Clean Development Mechanism under the Kyoto Protocol. Presented at the experts' workshop, "Dealing with Carbon Credits after Kyoto," Callantsoog, the Netherlands.

Panayotou, T., 1998: Six questions of design and governance. In: Issues & Options: The Clean Development Mechanism. United Nations Development Programme.

Rolfe, C., May 1998: Additionality: What Is It? Does It Matter? Report Prepared for the Technical Committee of the Greenhouse Gas Emission Reduction Trading Pilot Project. West Coast Environmental Law Association.

Sokona, Y., S. Humphries, and J.-P. Thomas, 1998: What prospects for Africa? In: Issues & Options: The Clean Development Mechanism. United Nations Development Programme.

Swiss AIJ Pilot Program (SWAPP), 1998: SWAPP Program Overview. Available from http://www.admin.ch/swissaij/.

UNFCCC, March 18, 1998: FCCC/CP/1997/7/Add.1. Kyoto Protocol to the United Nations Framework Convention on Climate Change.

UNFCCC, June 11, 1998: FCCC/SB/1998/MISC.1/Add.5. Indonesia (on behalf of the Group of 77 and China). Position Paper of G-77 and China at the Third Meeting of the Joint SBI/SBSTA Contact Group on the Mechanisms of the Kyoto Protocol.

United States Initiative on Joint Implementation, 1994: Guidelines for a USIJI Project Proposal. Available from http://www.ji.org/usiji/guide.shtml.

The World Bank, December 13, 1995: Norway — World Bank Group: 1996-1998 Collaborative Program on Activities Implemented Jointly under the FCCC AIJ Pilot Phase. Global Environment Division, Environment Department.

World Resources, 1998: A Guide to the Global Environment: Environmental Change and Human Health (WRR) [World Resources Institute, UNDP, UNEP, and the World Bank Group (eds.)]. Oxford University Press, Oxford, England.

Yamin, F., 1998: Unanswered questions. In: Issues & Options: The Clean Development Mechanism. United Nations Development Programme.

Glossary of Abbreviations

AIJ	Activities Implemented Jointly
ALGAS	Asia Least Cost Greenhouse Gas Abatement Study
BAU	Business as usual
CDM	Clean Development Mechanism
CCGT	Combined cycle gas turbine
CERs	Certified Emission Reductions
CFL	Compact fluorescent lamp
CH_4	Methane
CHP	Combined heat and power
CO	Carbon monoxide
CO_2	Carbon dioxide
COP-3	Third Conference of the Parties to the Convention (November 1997 in Kyoto)
COP-4	Fourth Conference of the Parties of the Convention (November 1998 in Buenos Aires)
DSM	Demand-side management
EITs	Economies in Transition
EU	European Union
FDI	Foreign Direct Investment
GEF	Global Environment Facility
GDP	Gross domestic product
GHGs	Greenhouse gases
GNP	Gross National Product
IDB	Inter-American Development Bank
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquefied petroleum gas
N_2O	Nitrious Oxide
NGO	Non-government organisation
NGV	Natural gas vehicle
NO_X	Nitrogen Oxide
ODA	Official development assistance
OECD	Organisation for Economic Cooperation and Development
PV	Photovoltaic
RETs	Renewable energy technologies
SFM	Sustainable forest management

SO_2	Sulfur Dioxide
TPES	Total primary energy supply
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change

UNITS OF MEASUREMENT

m	metre
ha	hectare
l	liter
g	gram
W	Watt
W_P	Peak watt
J	Joule
ton	2000 pounds (American)
tonne	1000 kg
toe	tonne of oil equivalent
tce	tonne of coal equivalent
k	kilo (10^3)
M	mega (10^6)
G	giga (10^9)
T	tera (10^{12})
P	peta (10^{15})

United Nations Development Programme

The United Nations Development Programme (UNDP) is the UN's largest source of grants for development co-operation. Its funding is from voluntary contributions of Member States of the United Nations and affiliated agencies. A network of 132 country offices — and programmes in more than 170 countries and territories — helps people to help themselves. In each of these countries, the UNDP Resident Representative normally also serves as the Resident Co-ordinator of operational activities for development of the United Nations system as a whole. This can include humanitarian as well as development assistance.

UNDP's main priority is poverty eradication. Its work also focuses on the closely linked goals of environmental regeneration, the creation of sustainable livelihoods, and the empowerment of women. Programmes for good governance and peace building create a climate for progress in these areas. Country and regional programmes draw on the expertise of developing country nationals and non-governmental organisations, the specialised agencies of the UN system and research institutes. Seventy-five per cent of all UNDP-supported projects are implemented by local organisations.

Ninety per cent of UNDP's core programme is focussed on sixty-six countries that are home to ninety per cent of the world's extremely poor. UNDP is a hands-on organisation with eighty-five per cent of its staff in the countries that it supports.

World Resources Institute

The World Resources Institute (WRI) is an independent center for policy research and technical assistance on global environmental and development issues. WRI's mission is to move human society to live in ways that protect the Earth's environment and its capacity to provide for the needs and aspirations of current and future generations.

Because people are inspired by ideas, empowered by knowledge, and moved to change by greater understanding, the Institute provides — and helps other institutions provide — objective information and practical proposals for policy and institutional change that will foster environmentally sound, socially equitable development. WRI's particular concerns are with globally significant environmental problems and their interaction with economic development and social equity at all levels.

The Institute's current areas of work include economics, forests, biodiversity, climate change, energy, sustainable agriculture, resource and environmental information, trade, technology, national strategies for environmental and resource management, business liaison, and human health. In all of its policy research and work with institutions, WRI tries to build bridges between ideas and action, meshing the insights of scientific research, economic and institutional analyses, and practical experience with the need for open and participatory decision-making.