United Nations Framework Convention on Climate Change

UNFCCC RESOURCE GUIDE

FOR PREPARING THE NATIONAL COMMUNICATIONS OF NON-ANNEX I PARTIES

MODULE 4
MEASURES TO MITIGATE CLIMATE CHANGE

UNFCCC

UNFCCC
United Nations Framework Convention on Climate Change

RESOURCE GUIDE FOR PREPARING THE NATIONAL COMMUNICATIONS OF NON-ANNEX I PARTIES

MODULE 4:

MEASURES TO MITIGATE CLIMATE CHANGE

TABLE OF CONTENTS

TABLE OF CONTENTS

I. INTRODUCTION

Measures to mitigate climate change are defined as any human (anthropogenic) intervention that can either reduce the sources of greenhouse gas (GHG) emissions (abatement) or enhance their sinks (sequestration).

This module has been developed to assist Parties not included in Annex I to the Convention (non-Annex I Parties) in preparing the mitigation section of their national communications to the United Nations Framework Convention on Climate Change (UNFCCC). It provides the reader with an overview of mitigation in the context of climate change, sustainable development and the framework of the UNFCCC.

The module on measures to mitigate climate change is one of four that will ultimately comprise a complete *UNFCCC Resource Guide for preparing the national communications of non-Annex I Parties.*[1] The Resource Guide is intended as a supplement to the *User manual for the guidelines on national communications from non-Annex I Parties*[2], which supports the implementation of Article 8, paragraph 2(c) of the Convention.

After reading this module readers should:

- Be able to understand the process of conducting an assessment of measures to mitigate climate change, including determining key parameters to identify mitigation potentials;
- Understand better the mitigation potential in different sectors;
- Have gained greater knowledge of the complexity and difficulties of developing baseline scenarios, as well as an awareness of the suitability of different models;
- Have gained an overview of modeling tools to evaluate mitigation options;
- Understand better the requirements for preparing national communications.

1.1 KEY SOURCES OF RELATED INFORMATION

- *"Emissions Scenarios. Special Report of the Intergovernmental Panel on Climate Change."* <http://www.ipcc.ch/ipccreports/index.htm>
- *"Methodological and Technological Issues in Technology Transfer"* <http://www.ipcc.ch/ipccreports/index.htm>
- *"Climate Change 2001: Mitigation. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change"* <http://www.ipcc.ch/ipccreports/index.htm>
- *"Climate Change 2007"* <http://www.ipcc.ch/ipccreports/index.htm>
- *"Greenhouse Gas Mitigation Assessment: A Guidebook"* <http://ies.lbl.gov/iespubs/iesgpubs.html>
- *"User manual for the guidelines on national communications from non-Annex I Parties."* <http://unfccc.int/national_reports/non-annex_i_natcom/guidelines_and_user_manual/items/2607.php>

A full list of references and resources can be found at the end of this module.

[1] Referred to as the Resource Guide throughout this document.
[2] The User Manual can be downloaded in English, French and Spanish from the UNFCCC website <http://unfccc.int/national_reports/non-annex_i_natcom/guidelines_and_user_manual/items/2607.php>.

II. BACKGROUND: THE SCIENCE OF CLIMATE CHANGE

This chapter provides a brief introduction to the science of climate change. The Intergovernmental Panel on Climate Change (IPCC) releases a comprehensive three-volume report every five years that summarizes the latest findings on climate change. The IPCC's Fourth Assessment Report (AR4) was released in 2007.

The IPCC has three working groups. Working Group I assesses the science of climate change, Working Group II assesses impacts, adaptation and vulnerability, and Working Group III assesses the mitigation of climate change. All reports are available online at <http://www.ipcc.ch/ipccreports/index.htm> .

2.1 GREENHOUSE GASES IN THE ATMOSPHERE

Global atmospheric concentrations of GHGs have increased markedly as a result of human activity since 1750 and now far exceed pre-industrial levels spanning many thousands of years, as determined from ice cores. Current atmospheric carbon dioxide (CO_2) and methane (CH_4) concentrations far exceed those spanning the last 650,000 years.

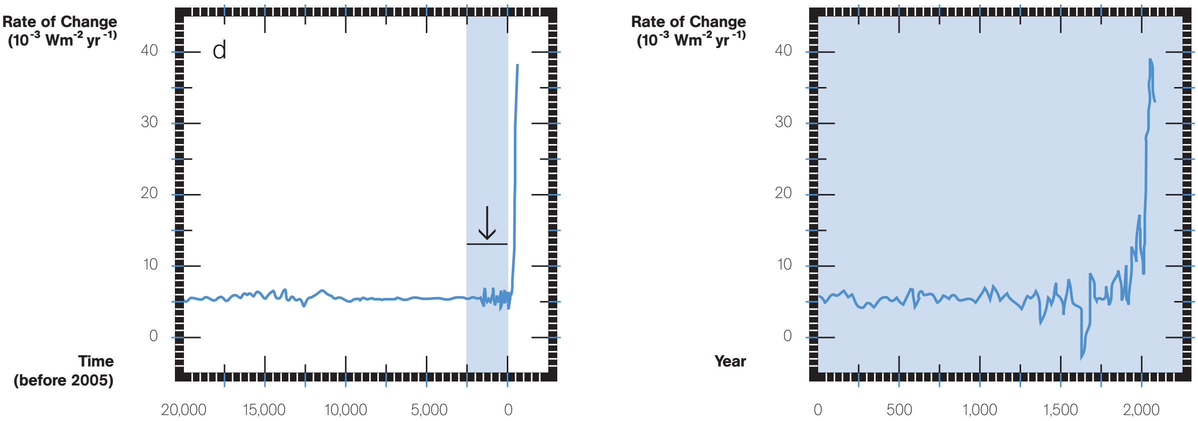
The increase in CO_2 is primarily due to changes in fossil fuel use and land use, while the increases in CH_4 and nitrous oxide (N_2O) are primarily due to agricultural activity. CO_2 is the most important anthropogenic GHG. The global atmospheric concentration of CO_2 has increased from a pre-industrial value of about 280 ppm (parts per million) to 379 ppm in 2005. The atmospheric concentration of CO_2 in 2005 far exceeded the natural range over the last 650,000 years (180 to 300 ppm). (IPCC 2007, Working Group I)

2.2 CURRENT SOURCES OF GREENHOUSE GASES

CO_2 emissions from fossil fuels are currently over 26 gigatonnes (Gt) per year and growing rapidly, while emissions from deforestation and other land-use changes are approximately 6 Gt CO_2 per year. The largest growth in global GHG emissions between 1970 and 2004 has come from the energy supply sector, which saw an increase of 145 per cent. Transport emissions grew by 120 per cent, industry emissions by 65 per cent and land use, land use change, and forestry (LULUCF) emissions by 40 per cent.

Global energy intensity decreased by 33 per cent between 1970 and 2004. However, this has been offset by the combined effects of global income growth per capita (77 per cent) and global population growth (69 per cent).

Figure II-1. **Rate of change in radiative forcing of CO_2, CH_4 and N_2O combined over the last 20,000 years**



Source: Adapted from IPCC (2007). *Technical Summary*, WG I, p.25

The differences between countries in terms of income per capita, emissions per capita and energy intensity remain significant. In 2004, OECD countries held a 20 per cent share of the world's population, produced 57 per cent of the global gross domestic product (GDP) based on purchasing power parity (PPP), and accounted for 46 per cent of global GHG emissions (IPCC 2007, Working Group III).

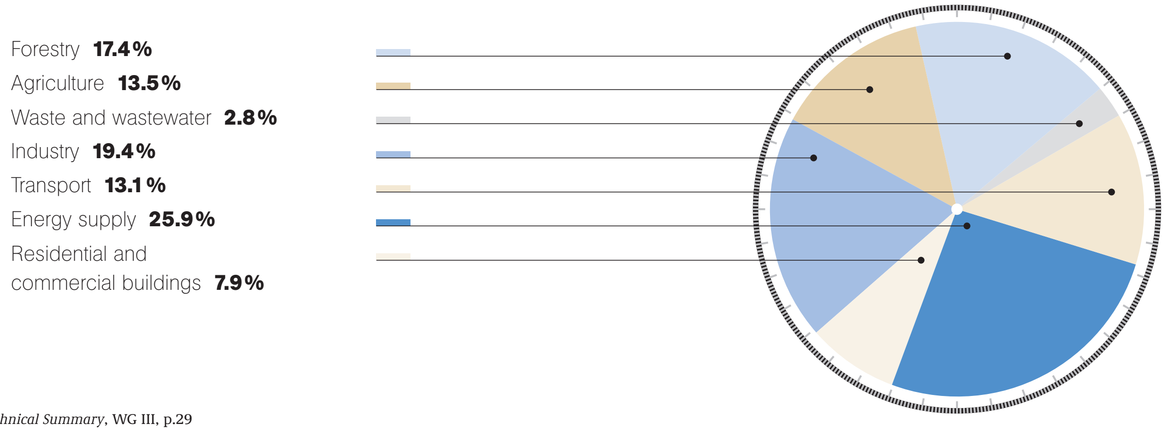
For detailed information on GHG emissions, please consult the IPCC Fourth Assessment Report (AR4) <http://www.ipcc.ch/ipccreports/index.htm>

2.3 IMPACTS OF CLIMATE CHANGE

The world is already seeing many changes that point towards an increasingly warm planet. For example, 11 of the last 12 years (1995–2006) rank among the 12 hottest years since 1850. The warming trend over the last 50 years (0.13°C per decade) is nearly twice that of the last 100 years and the total temperature increase from the period 1850–1899 to the period 2001–2005 has been 0.76°C.

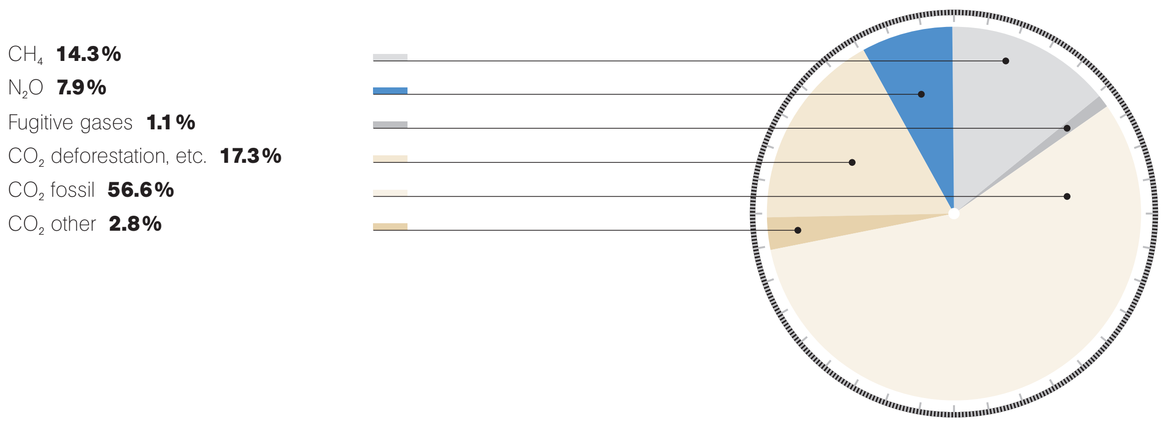
Unmitigated climate change will have a significant impact in many areas: the risk of floods and droughts is projected to increase in many regions – as much as 20 per cent of the world's population lives in areas that are likely to be affected by increased flood hazard by 2080; sea levels are expected to

Figure II-2. **Greenhouse gas emissions by sector in 2004**



Source: IPCC (2007). *Technical Summary*, WG III, p.29

Figure II-3. **Global anthropogenic greenhouse gas emissions in 2004**



Source: IPCC (2007). *Technical Summary*, WG III, p.28

rise between 0.2 m and 0.6 m, or possibly more, by 2100; tropical and extra-tropical cyclones will become more intense; increased flooding and the degradation of freshwater, fisheries and other resources could affect hundreds of millions of people; the impact on agriculture will also be severe; millions of people are likely to face malnutrition; and increases in infectious disease vectors are also expected.

Climate change is likely to amplify existing inequalities; poorer nations are more vulnerable to climate change and have a lower capacity to adapt due to inadequate financial, institutional, technological and knowledge capabilities. The effects will be worse in developing countries that are already experiencing more floods or are prone to drought, but which have a large share of the economy in climate-sensitive sectors. Any impact will disproportionately hit the poorest and will exacerbate inequities in health status and access to adequate food, clean water and other resources.

Averting catastrophic climate change and stabilizing atmospheric GHG concentrations will require significant emissions reductions. The IPCC Special Report on Emissions Scenarios (SRES, 2000) provides scenarios for future GHG emissions, which are accompanied by 'storylines' of social, economic and technological development.

For detailed information on the effects of climate change, please consult the Working Group II and Working Group III contributions to the IPCC AR4 and the Special Report on Emissions Scenarios, which are available at: <http://www.ipcc.ch/ipccreports/index.htm>.

2.4 ATTRIBUTES OF KEY GREENHOUSE GASES

The greenhouse effect is a natural phenomenon that maintains the earth's average temperature at about 15°C. It is caused by gases in the atmosphere that absorb heat energy from the sun. These gases are referred to as GHGs. Without the greenhouse effect, the earth would be uninhabitable: heat would escape back into space and the Earth's average temperature would be about minus 18°C. However, since the dawn of the Industrial Revolution in the early 1800s, humans have been significantly increasing the levels of GHGs in the atmosphere, primarily through the combustion of fossil fuels and the clearing of forested land, thus altering the balance of earth's natural carbon cycle. The increase in these gases is the basis of anthropogenic climate change.

The Kyoto Protocol covers six GHGs[4]. Each GHG has specific properties, such as its atmospheric lifetime and its ability to absorb radiation. TABLE II-1 summarizes the most important characteristics of some of the gases covered by the UNFCCC.

Table II-1. **Attributes of key greenhouse gases**

	CO_2	CH_4	N_2O	CFC-11	HFC-23	PFC-14
Pre-industrial concentration	280 ppm	700 ppm	270 ppb	0	0	40 ppt
Current concentration	379 ppm	1,774 ppm	319 ppb	251 ppt	5.6 ppt	74 ppt
Change in concentration since 1998	13 ppm	11 ppm	5 ppb	–13 ppt	4 ppt	
Global warming potential (100 years, IPCC 2007)	1	25	298	4,750	14,800	7,390
Previous estimate of global warming potential (100 years, IPCC 1995)	1	21	310	3,800	11,700	6,500
Atmospheric lifetime	Not applicable*	12	114	45	270	50,000

Source: Information taken from AR4, Working Group I, p.33 and 141.
Abbreviations: ppm = parts per million, ppb = parts per billion, ppt = parts per trillion.

*CO_2 does not have a mean lifetime. CO_2 emissions are absorbed by oceans and by the terrestrial biosphere. About half of the CO_2 emitted into the atmosphere is removed in the first 30 years, a further 30 per cent is removed within a few centuries and the remaining 20 per cent will typically stay in the atmosphere for many thousand years.

The figures above show the latest global warming potentials (GWPs) from the IPCC's Fourth Assessment Report, as well as the GWPs reported in the Second Assessment Report, from 1995. Note that the UNFCCC Guidelines currently recommend that Parties use the 1995 values for their national communications[5].

4 The six GHGs listed in the Kyoto Protocol are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

5 The UNFCCC's User Manual states that non-Annex I Parties wishing to report on aggregated GHG emissions and removals expressed in CO_2 equivalents should use the GWP provided by the IPCC in its Second Assessment Report ("1995 IPCC GWP Values") based on the effects of GHGs over a 100-year period.

III. THE IPCC MITIGATION REPORTS

The mitigation volumes of the IPCC's Third Assessment Report (TAR) and AR4 were released in 2001 and 2007 respectively. These volumes are excellent resources for Parties conducting mitigation assessments and both are freely available online at <http://www.ipcc.ch/ipccreports/index.htm>. Although the AR4 is more recent, it is not intended to replace the TAR. Instead it elaborates on TAR and updates the results with more recent findings.

The TAR volume discusses GHG emissions scenarios, including the technological and economic potential for, and barriers to, mitigation options and sinks. It also elaborates on mitigation policies and their cost.

The focus of the AR4 volume is on mitigation options for energy supply, transport, buildings, industry, agriculture, forestry and waste management. It elaborates on the measures that could be employed, the costs and specific barriers, and policy implementation issues. In addition, estimates are given for the overall mitigation potential, and costs at a sectoral and global level.

IV. THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

The United Nations Framework Convention on Climate Change (UNFCCC) aims to address the threat of anthropogenic (human induced) climate change at an international level. It came into force in 1994 and has been ratified by 192 countries. The framework seeks the "stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Article 2 of the Convention). The Conference of the Parties (COP) is the highest decision-making authority of the Convention.

4.1 PARTIES TO THE CONVENTION

Parties to the UNFCCC are expected to "take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects" (Article 3.3). Parties have "common but differentiated responsibilities" based on their national circumstances (Articles 3.1 and 4.1). Each Party is committed to:

- Gathering and sharing information on GHG emissions, national policies and best practices;
- Formulating strategies for addressing GHG emissions and adapting to the expected impacts;
- Cooperating in preparing for adaptation to the impact of climate change.

The UNFCCC differentiates between three different groups of Parties:

- Annex I comprises those countries that were OECD members in 1992 as well as countries with economies in transition (EIT);
- Annex II comprises the OECD members of Annex I;
- Non-Annex I Parties are primarily the developing nations.

4.2 THE UNFCCC GUIDELINES ON MITIGATION ASSESSMENT

Under the UNFCCC, each Party has to report its GHG emissions and its mitigation and adaptation strategies in its national communications. More specifically, each Party has to submit to the COP a GHG inventory with information on its emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol. Furthermore, each Party has to submit a mitigation plan detailing the steps taken or envisaged by the Party to implement the Convention.

The UNFCCC's Guidelines for the preparation of national communications from non-Annex I Parties[6] were adopted by COP 8, in 2002. These guidelines also serve as policy guidance to ensure the timely provision of any financial support needed by non-Annex I Parties in order to fulfill their requirement to report to the UNFCCC.

National communications from non-Annex I Parties have to include a range of detailed and country-specific data. They should provide a description of national and regional development priorities, objectives and circumstances on the basis of which they will address climate change and its adverse impacts. This may include information on geography, climate and economy and any subsequent effect on their ability to mitigate and adapt to climate change, as well as information regarding specific needs or concerns arising from the adverse effects of climate change.

[6] Available online at <http://unfccc.int/resource/docs/cop8/07a02.pdf#page=2>

V. MITIGATION ASSESSMENTS: CONCEPTS, STRUCTURE AND STEPS

In the context of the UNFCCC, a mitigation assessment is a national-level analysis of the various technologies and practices that have the capacity to mitigate climate change.

Typically, mitigation assessments include the development of one or more long-term mitigation scenarios. A mitigation scenario is a quantified projection of how future GHG emissions can be reduced relative to one or more baseline scenarios. A baseline scenario characterizes the likely evolution of GHG emissions in the absence of new, specific policies to reduce GHG emissions. A mitigation assessment, therefore, involves creating both baseline and mitigation scenarios.

It is important to note that, for many Parties, mitigation does not necessarily imply an absolute reduction in emissions in relation to a given base year, rather it implies a reduction relative to what emissions would otherwise have been in the future in the absence of specific GHG mitigation action, that is, relative to a counterfactual baseline scenario.

A mitigation assessment provides policy makers with an evaluation of technologies and practices that can mitigate climate change and also contribute to national development objectives. The assessment also identifies potential project and programme investments and provides an outline of the cost of avoiding climate disruption.

This chapter introduces some of the key issues that need to be addressed when conducting a mitigation assessment. It is useful to bear in mind that developing a full national action plan on mitigation goes beyond the scope of a mitigation assessment.

5.1 SCOPE

The scope of a mitigation assessment can include an analysis of:

- Energy demand and supply, forestry, agriculture, rangelands and waste management;
- The macro-economic impacts of different options;
- The legislation, policies and programmes that facilitate the rapid implementation of mitigation technologies and practices.

5.2 STEPS

Any mitigation assessment should focus on clearly defined objectives and emphasize implementation. The basic steps will depend on the objectives and the scope of the assessment, but should include:

- Collecting data;
- Assembling base year or historical data on activities, technologies, practices and emission factors;
- Calibrating base year energy and emissions calculations with available standardized statistics such as national energy balances and/or national emissions inventories;
- Preparing baseline scenarios;
- Screening mitigation options;
- Preparing mitigation scenarios and sensitivity analyses;
- Assessing the social, economic or environmental impacts;
- Developing an overall mitigation strategy;
- Preparing reports.

5.3 KEY PARTICIPANTS

The development of mitigation assessments requires close cooperation among a wide range of stakeholders; energy, environment and finance ministries will all need to be involved while some tasks may be undertaken by outside consultants or the academic community. The expert skills of statisticians, energy policy experts, engineers, modellers and technical writers will be required.

However, mitigation assessments are not simply technocratic exercises; they should also involve a much broader judgment on how mitigation activities can constitute part of national development priorities. It is therefore important to involve not only a diverse group of government agencies, but also non-governmental stakeholders.

To maximize mitigation measures, any national mitigation strategy should also aim to increase public awareness of climate change.

5.4 TIME FRAME

Ideally, a mitigation assessment should be a long-term assessment, in order to reflect economic lifetimes and the potential for the stock turnover of major technologies, which can be 40 years or more in the energy sector. However, establishing long-term projections can be difficult, especially in developing countries, owing to uncertainties over future development pathways and limited statistical data. Shorter-term assessments (10–20 years) based on national plans and sectoral assessments are more practical for most developing countries. Further aggregate assessments of long-term trends can complement these shorter-term assessments.

5.5 RESULTS

Defining the type of outputs desired from a mitigation assessment will help in selecting the areas where efforts should be focused. The outputs of a typical mitigation assessment will consist of economic indicators, GHG emissions, local environmental impacts and social impacts of mitigation options. A mitigation assessment should also discuss any barriers to implementing mitigation options and describe policies to overcome them.

5.6 METHODOLOGY AND DATA COLLECTION

The type of analytical methodology chosen for a mitigation assessment should reflect the desired level of detail of its results, the availability of data and, perhaps most crucially, the level of technical expertise available to those conducting the assessment. For more information on methodologies, see CHAPTER VIII.

Depending on the methodology, it may be sufficient to collect data for a base year only, or it may be necessary to collect historical time series data if, for example, econometric methods are used. The focus should be on collating secondary data; collecting some primary data may be required however, and assumptions and expert judgments will always be needed in order to fill any gaps in the data and to help formulate projections for future trends.

5.7 TREATMENT OF COSTS

Any action taken to mitigate climate change may cause economic resources to be diverted away from alternative uses. Mitigation assessments should attempt to estimate the value of these resources using cost-benefit analysis techniques. Incremental costs are normally measured relative to a “no action” counterfactual baseline. As far as possible, assessments should try to include all costs, but bear in mind that technical options, including many energy-efficiency measures, may have negative costs in terms of economic benefits, for example. It may not make sense to specify a cost for other non-technical actions involving various options at a social level. Examples of this type of action include campaigns to encourage the public to waste less energy or efforts to develop less energy-intensive urban environments. Both types of actions are typically referred to as “no regrets” actions.

5.8 DISCOUNTING

The discount rate represents the return on investment required to justify the expenditure of scarce social resources. This, in turn, reflects the degree to which society prefers to receive benefits in the present rather than the future. In terms of the economics of climate change, there are those who argue that the future benefits provided by GHG abatement should be discounted at a rate equal to the average return on a typical private-sector investment (Nordhaus, 1994).

However, critics argue that the use of high positive discount rates (e.g. 6 per cent) can support policy outcomes that are unfair on future generations because unmitigated climate change would impose major, uncompensated costs on posterity. Similarly, some argue that equal weight should be attached to the welfare of both present and future generations. Economists have long recognized that the use of low discount rates (e.g. 1 per cent) supports aggressive steps to stabilize global climate (Cline, 1992).

5.9 LINKS TO GHG INVENTORIES AND VULNERABILITY AND ADAPTATION ASSESSMENTS

Because of long lag times in the climate system, no mitigation efforts will be able to prevent climate change completely. Conversely, reliance on adaptation alone would lead to a greater degree of climate change, to which it would be very expensive, and possibly even impossible, to adapt. Thus, increasingly, there are calls to better integrate adaptation and mitigation strategies and seek synergy between the two.

In terms of national communications, mitigation assessments should be closely linked to GHG inventories and vulnerability and adaptation (V&A) assessments. It is important to ensure that each communication is consistent with regard to its use of data and assumptions (e.g. demographic and economic assumptions). Reports on these three elements should be closely coordinated, for example: GHG inventories identify the major sources and sinks of GHG, and can, therefore, help to determine the scope and nature of a mitigation assessment; mitigation assessment accounts should use the GHG inventories' accounting procedures and emission factors wherever possible; and ideally, members of the team working on national GHG inventories would also participate in the mitigation assessment. Similarly, V&A assessments will identify possible changes in natural resource conditions and management practices, which could in turn affect baseline resource conditions, as well as the applicability of mitigation options. For example, climate change might affect hydro potential, irrigation energy requirements, and biomass productivity, or alter the effectiveness of mitigation strategies such as afforestation or the reduction of agricultural emissions.

5.10 BASELINE SCENARIOS

As noted previously, a baseline scenario is a plausible and consistent description of how a system might evolve in the future in the absence of explicit new GHG mitigation policies. Baseline scenarios are the counterfactual situations against which mitigation policies and measures will be evaluated. A baseline should not be considered as a forecast of what *will* happen in the future, since the future is inherently unpredictable and depends, in part, on planning and policy adoption. Assessments will typically require one or more baseline scenarios as baselines are highly uncertain over the long term and may prove controversial, particularly in developing countries.

Ideally, multiple baseline scenarios should be constructed to reflect any uncertainties (i.e. a sensitivity analysis). Each baseline requires separate mitigation analyses although, in practice, a suitable balance will need to be struck between this ideal and maintaining a manageable assessment. Reasonable baselines are critical to a mitigation analysis since mitigation scenarios are largely judged on the basis of the *incremental* costs and benefits *relative* to the baseline scenario.

Baselines should not be a simple extrapolation of current trends. They should consider the possible evolution of activities that affect GHG sources and sinks, including consideration of:

- Macroeconomic and demographic trends;
- Structural shifts in the economy;
- Projections of the main GHG emitting activities and sinks;
- The evolution of technologies and practices, including saturation effects and the likely adoption of efficient technologies that affect GHG emissions.

5.11 SCREENING OF MITIGATION OPTIONS

Screening enables a rough assessment of options to be made ahead of performing a more detailed mitigation scenario analysis.

Screening is particularly important when using bottom-up methodologies in which a wide range of technologies and policies need to be considered.

One approach to screening is to assign scores or rankings to mitigation options in order to identify those that need to be included later on in a more in-depth analysis. Screening reduces the level of effort required to conduct an in-depth mitigation analysis, while also reducing the likelihood of overlooking important options. Screening may include a quantitative assessment of the mitigation potential (t CO_2) and the cost of saved carbon ($/t C) of each option and it can also include qualitative factors. Screening criteria should be consistent with the overall framing of mitigation scenarios.

Possible screening criteria include the following:

- The potential for a large impact on GHG emissions;
- Consistency with national development goals;
- Consistency with national environmental goals (e.g. reduction of local air pollutants, protection of biodiversity, and watershed management);
- Data availability;
- Political feasibility;
- Replicability (i.e. adaptability to different geographical, socio-economic-cultural, legal, and regulatory settings);
- Cost-effectiveness;
- Project-level considerations, such as capital and operating costs;
- Macro-economic considerations, such as: the impact on GDP; the number of jobs created or lost; effects on inflation or interest rates; the implications for long-term development; foreign exchange and trade, etc.

A screening cost curve can be used for ranking GHG mitigation options (see Figure V-4). For example, cumulative GHG reduction from successive mitigation options (t CO_2 avoided) can be plotted against the cost per unit of GHG reduction ($/t C); in this figure, the area under the cost curve yields the total cost of avoided emissions. Consideration should be given to interdependencies among options, for example, benefits such as fuel switching in the electric sector may be reduced by end-use efficiency programmes.

5.12 MITIGATION SCENARIOS

Mitigation scenarios reflect a future in which explicit policies and measures are adopted to reduce the sources (or enhance the sinks) of GHGs, and are used to compare and evaluate GHG mitigation policies and measures against the counterfactual situation described in the baseline scenario.

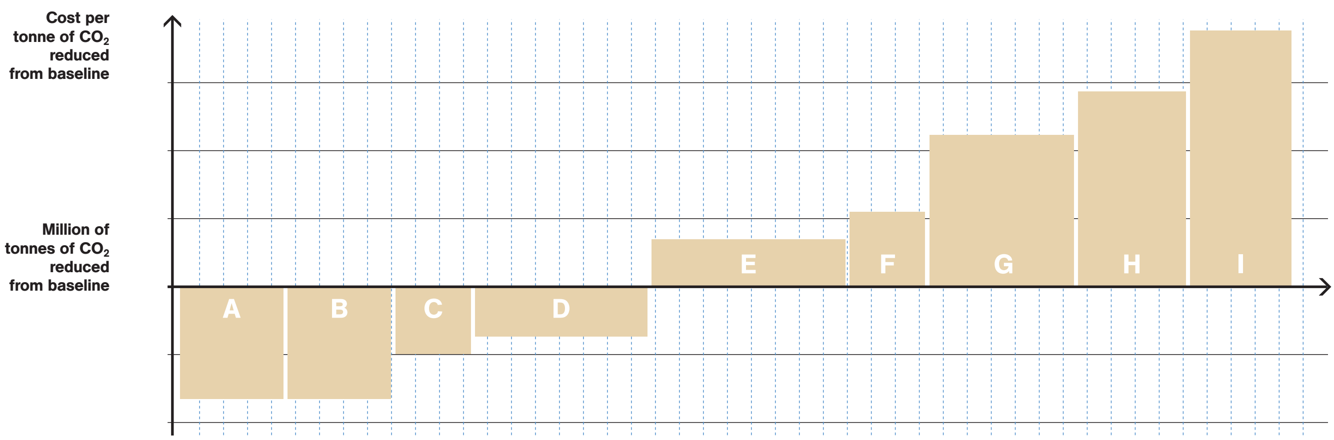
GHG mitigation scenarios should take into account the common but differentiated responsibilities of the Parties and their specific national and regional development priorities, objectives and circumstances. They should not simply reflect current plans, but should instead assess what would be hypothetically achievable based on the goals of the scenario.

A mitigation scenario might reflect only the technical potential for reducing GHG emissions or storing carbon, or it may incorporate estimates of what would be achievable after consideration of the other factors (institutional, cultural, legal, etc.) that may limit the feasibility of the options that are technically available. Ideally, both the technical and the achievable potential should be reported.

Mitigation scenarios can be constructed in a number of ways. For example they may be based upon:

- An emission reduction target which, in turn, may be specified relative to the baseline, relative to emissions in a given historical year, or relative to an indicator such as emissions per capita or emissions per unit of GDP;
- The inclusion of all options up to a certain cost per unit of emissions reduction (equivalent to a carbon tax);
- The inclusion of only "no regrets" options (i.e. options that have no positive cost per unit of emissions reduction);
- Specific options or technologies, based on perceived technical or political feasibility.

Figure V-4. **A screening cost curve**



Source: Sathaye and Meyers. *Greenhouse Gas Mitigation Assessment: A Guidebook* (1995)

VI. MITIGATION OPTIONS: A SECTORAL REVIEW

Numerous technological solutions offer substantial CO_2 reduction potential, including energy production from renewable sources and substantial increases in energy-efficiency through new technologies and smart design. A combination of technological solutions and policy measures will be necessary to achieve the low carbon economy required to stabilize the climate. Individual countries or regions will need to employ different combinations of technologies in order to best serve their needs and to take advantage of their indigenous resources.

Improvements in energy efficiency produce a wide range of benefits across all sectors of the economy; new investments in power generation, industry, transportation, and building infrastructure could be substantially more efficient than existing stock. Improvements in that area could reduce GHG emissions, prevent pollution, alleviate poverty, improve security in the supply of energy, increase competitiveness and improve health and employment opportunities.

Energy-intensive activities are increasing rapidly in developing countries, where, compared with industrialized countries, a larger proportion of the opportunities for improving energy efficiency is associated with new installations (rather than the modification of existing installations). The potential for energy efficiency improvement is, therefore, often greater in developing countries. Initial results from more than 300 studies in 24 non-Annex I countries show that upgrading energy efficiency and switching to low-carbon fuels for power supply hold the greatest potential for such savings (Linden ET AL., 1999).[7] However, low and subsidized energy prices in many developing countries mean that the market has not encouraged the use of efficient technologies, while, similarly, many commercial technologies for improving energy efficiency have not been readily available in those countries. Further discussion about barriers to mitigation follows in CHAPTER VII.

The following sections provide an overview of the mitigation potential in the industry, building, transportation, energy supply, land use and waste sectors. For a more detailed discussion please consult the IPCC AR4 on Mitigation at: <http://www.ipcc.ch/ipccreports/index.htm>.

6.1 ENERGY SUPPLY

The energy supply sector is responsible for almost a quarter of total GHG emissions. It includes industries involved in the extraction of primary energy, those that transform energy supplies from primary fuels into secondary fuels, and those that are involved in transporting energy. It includes modern sectors, such as electric generation, oil refining, ethanol production, coal mining, and oil production, as well as traditional sectors such as charcoal production.

6.1.1 MITIGATION MEASURES

Mitigation measures in the energy supply sector include: increasing plant efficiency; switching to lower-carbon fuels; reducing losses in the transmission and distribution of electricity and fuels; and increasing the use of renewable energy forms, such as solar, hydropower, ocean, wind, biomass, and geothermal energy.

6.1.2 POLICIES FOR MITIGATION

Market-based instruments include GHG and energy taxes, cap-and-trade systems and subsidies for renewable energy. Regulatory measures consist of specifying the use of low-carbon fuels, performance and emissions standards. Hybrid measures include tradable emissions permits and renewable portfolio standards. Government funded research, development and demonstration activities are also vital in establishing a low-carbon energy supply sector.

6.2 TRANSPORTATION

In 2004, transport was responsible for 13 per cent of total GHG emissions; petroleum currently supplies 95 per cent of total energy needs in that sector. Road transport accounts for 74 per cent of transport energy use and light-duty vehicles alone comprise about 50 per cent of all road transport. Air travel is the second largest and most rapidly growing mode of transport and is responsible for about 12 per cent of current energy use in the transport sector.

Emissions from road transport are a result of many factors, such as:

- Activity: the quantity of transport duties undertaken;
- Structure: the split between different modal shares (road, rail, air, water);

- Intensity: the efficiency with which energy is used to complete travel duties;
- Fuel: the types of fuel used to power transport.

The growth of energy use in the transport sector, its continued reliance on petroleum and the consequent increase in carbon emissions are determined by long-term trends of the increasing motorization of world transport systems and an ever-growing demand for mobility. GHG emissions in the transport sector are growing more rapidly than in any other. Moreover, emissions from transport in developing countries are increasing faster than in other regions of the world.

6.2.1 MITIGATION MEASURES

Mitigation measures in the transport sector include fuel-efficiency improvements, such as changes in vehicle and engine design (e.g. hybrids), and alternative low-carbon fuel sources such as biofuels and compressed natural gas (CNG). A comprehensive mitigation strategy in this sector may also include the expansion of public transport infrastructure. Public transport technologies such as buses and trains can generally operate with much lower emissions per passenger per km than cars or airplanes. Improved land-use planning (dense settlements instead of urban sprawl) is also an important mitigation option in the longer term.

6.2.2 POLICIES FOR MITIGATION

Government policies can include a combination of market-based programmes and regulatory measures. Market-based programmes include increases in fuel taxes, incentives for mass transport systems, and fiscal incentives and subsidies for alternative fuels and vehicles.

Regulatory instruments include fuel economy standards, mandates on vehicle design or alternative fuels, and direct investment by governments in infrastructure improvements, research and development.

6.3 BUILDINGS

In 2004, CO_2 emissions from the building sector were around 8.6 Gt CO_2, accounting for about 8 per cent of total GHG emissions.

6.3.1 MITIGATION MEASURES

There are many cost-effective technologies and measures that have the potential to significantly reduce the increase in GHG emissions from buildings. Examples include: energy-efficient heating and cooling systems, lighting, air conditioners, appliances and motors; improving building thermal integrity though insulation and air sealing; using solar energy in active and passive heating and cooling; and effectively using natural light (“daylighting”).

6.3.2 POLICIES FOR MITIGATION

Government policies may include a combination of market-based programmes and regulatory measures. Market-based programmes include: incentives for consumers to use new energy-efficient products (in many situations, the fate of less efficient second-hand equipment must also be considered); incentives for manufacturers to develop energy-efficient products; and government or large-customer procurement for energy-efficient products.

Regulatory measures, if well enforced, can be highly effective. Such measures include mandates on energy-efficiency performance standards, building codes, appliance efficiency standards and efficiency labelling.

6.4 INDUSTRY

Energy-related CO_2 emissions from the industrial sector grew from 6.0 Gt CO_2 in 1971 to 9.9 Gt CO_2 in 2004. Industry is responsible for almost 20 per cent of total GHG emissions. Since 1980, industrial energy demand has stagnated in industrialized countries, but continues to grow rapidly in many developing countries, especially in Asia.

Although there is significant potential for improving energy efficiency in all industries, the greatest opportunities for savings are in the energy-intensive industries. Five of these – iron and steel, chemicals, petroleum refining, pulp and paper, and cement – account for roughly 45 per cent of global industrial energy consumption. Energy purchases represent such a large fraction of production costs in these industries that new technologies for producing basic materials have been more energy-efficient than the technologies they replaced, a trend that is likely to continue.

[7] Linden ET AL. (1999). *Potential and Cost of Clean Development Mechanism Options in the Energy Sector: Inventory of Options in Non-Annex I Countries to Reduce GHG Emissions.* ECN-C–99-095, Petten. Available online: <http://www.ecn.nl/docs/library/report/1999/c99095.pdf>

6.4.1 MITIGATION MEASURES

Mitigation measures in the industrial sector include process changes to directly reduce CO_2 emissions, material-efficient product design, material substitution, and product and material recycling. In light industries, mitigation options to reduce GHG emissions include efficient lighting, efficient motors and drive systems, process controls, and saving energy in space heating.

6.4.2 POLICIES FOR MITIGATION

Introducing new regulations is the most direct method of changing industrial behaviour. Among the most viable options for influencing industry's use of energy are equipment efficiency standards, reporting and targeting requirements, and the regulation of utilities to encourage both the implementation of demand-side management programmes and the purchase of cogenerated electricity. By excluding sub-standard equipment from the market, equipment efficiency standards can have a large impact in a short time. They can also help to lower the price of higher efficiency equipment by increasing the size of the markets. Market-based policies such as cap-and-trade systems and offset programmes have also proven effective in controlling and mitigating emissions while, at the same time, fostering innovation and investment in new technologies.

Box IV-1. Non-CO_2 greenhouse gases

Non-CO_2 GHGs from manufacturing (HFCs, PFCs, SF_6, and N_2O) are increasing. Furthermore, PFCs and SF_6 have extremely long atmospheric lifetimes (thousands of years) and GWP values (thousands of times those of CO_2) that result in virtually irreversible atmospheric impacts.

Non-CO_2 GHGs include:

- Nitrous oxide (NOx) emissions from industrial processes;
- PFC emissions from aluminum production;
- PFCs and other substances used in semiconductor production;
- HFC-23 emissions from HCFC-22 production;
- SF_6 emissions from the production, use and decommissioning of gas insulated switchgear;
- SF_6 emissions from magnesium production and casting.

Fortunately, there are technically-feasible, low-cost emission reduction options available for a number of applications. The implementation of major technological advances has led to significant emission reductions of N_2O and the fluorinated GHGs produced as unintended by-products. On-going research and development efforts are expected to expand emission reduction options further.

6.5 AGRICULTURE

Agricultural areas (e.g. cropland, managed grassland and permanent crops including agro-forestry and bio-energy crops) occupy about 40–50 per cent of the earth's land surface. In 2005, agriculture accounted for an estimated 10–12 per cent of the total global anthropogenic GHG emissions (AR4 WGIII).

6.5.1 MITIGATION AND SEQUESTRATION MEASURES

Mitigation measures in the agricultural sector include improving rice cultivation and animal husbandry to minimize CH_4 emissions, decreasing the use of artificial fertilizer to minimize N_2O emissions and improving cultivation methods, such as the no-till approach, to increase carbon storage in soil.

6.5.2 POLICIES FOR MITIGATION AND SEQUESTRATION

Policies in the agricultural sector can include market-based mechanisms such as offset programmes and conservation easements, as well as regulatory measures in the form of incentives and taxes.

6.6 FORESTRY

Forest-related emissions accounted for about 17 per cent of global GHG emissions in 2005. Hundreds of millions of households depend on goods and services provided by forests and it is, therefore, particularly important to assess activities in the forestry sector that are aimed at mitigating climate change in the broader context of sustainable development and community impact (AR4, WG III).

6.6.1 MITIGATION AND SEQUESTRATION MEASURES

Mitigation measures include reforestation, protecting existing forests and substituting wood fuel with other fuels. In some situations, where wood fuel production is highly unsustainable, substituting household wood fuel with fossil fuels may paradoxically constitute a mitigation option.

6.6.2 POLICIES FOR MITIGATION AND SEQUESTRATION

Policies for forest protection and afforestation have to cover a wide range of areas and should include clarifying and securing land tenure for small farmers, the use of incentive programmes such as pay for conservation services, market mechanisms such as offset programmes for sequestration projects, and enforcing bans on logging in protected areas.

6.7 WASTE

Post-consumer waste accounts for less than 5 per cent of global GHG emissions, with a total of approximately 1.3 Gt CO_2 eq in 2005. Waste and waste management affect the release of GHGs through:

- Methane emissions during the anaerobic decomposition of the organic content of solid waste and wastewater;
- Reducing fossil fuel use by utilizing energy recovery from waste combustion;
- Reducing energy consumption and process gas releases in extractive and manufacturing industries, as a result of recycling;
- Carbon sequestration in forests, caused by a decrease in demand for virgin paper;
- Energy use in the transport of waste for disposal or recycling; except for the long-range transport of glass for reuse or recycling, transport emissions of secondary materials are often one or two orders of magnitude smaller than the other four factors (Ackerman, 2000).

6.7.1 MITIGATION MEASURES

Mitigation measures in the waste sector include source reduction through waste prevention, recycling, composting, waste-to-energy incineration and CH_4, capture from landfills and wastewater.

6.7.2 POLICIES FOR MITIGATION

Policies for waste minimization and GHG reduction include taxes on solid waste disposal (bag fees), market incentives (e.g. offsets) for improved waste management and recovery of CH_4, and regulatory standards for waste disposal and wastewater management (e.g. mandatory capture of landfill gas).

VII. BARRIERS TO MITIGATION

Many technologies and policies exist to reduce GHG emissions. Significant technical progress has been made in the last five years in a number of areas, including wind turbines, hybrid engine cars and underground CO_2 storage, but significant barriers still exist. These barriers add to the cost of implementation and reduce the achievable potential. They can be technical, economic, political, cultural, social, behavioral and institutional.

Barrier identification is a key issue when selecting feasible mitigation options. Potential mitigation opportunities or barriers vary by region and sector and can change over time. The identification, analysis and prioritization of barriers should be country-specific and actions should be tailored to overcome specific barriers, interests and influences; barriers generally do not disappear without intervention.

An obvious barrier is the lack of incentive for using low-GHG technologies and practices. The tendency for societies to focus their attention on particular types of technologies or patterns of development can prevent new, low-GHG emission technologies from entering the market. Meanwhile, it is important to recognize when major technologies begins to change, so that the opportunity can be taken to introduce low-emission alternatives.

Box VII-2. **Barriers and opportunities**

A **barrier** is defined as any obstacle to reaching a potential reduction of GHG that can be overcome by a policy, programme, or measure.

An **opportunity** is a situation or circumstance to decrease the gap between the market potential of a technology or practice and the economic, socio-economic, or technological potential.

Barriers and opportunities tend to be **context-specific**: they change over time and vary between countries.

Market potential indicates the level of mitigation expected to occur under forecast market conditions.

Technical potential describes the maximum amount of mitigation achievable through technology diffusion (if all technically feasible technologies were used in all relevant applications, without regard to their cost or user acceptability).

Economic potential represents the level of GHG mitigation that could be achieved if all technologies that are cost-effective from a consumer's point of view were implemented.

Table VII-2. **Types and sources of barriers**

Source of barrier and/or opportunity	Examples of market and/or institutional imperfections* (and subsequent opportunities)	Examples of social and cultural barriers (and subsequent opportunities)
Prices	• Missing markets (market creation) • Distorted prices (rationalization of prices, environmental regulations and taxes)	
Financing	• Financial market imperfections (sector reform or restructuring of economy) • Constraints of official development assistance (ODA) (removing tied aid and/or better targeting of ODA)	
Trade and Environment	• Tariffs on imported equipment and restrictive regulations (rationalization of customs tariffs)	
Market structure and functioning		• Circumstances requiring rapid payback (fuel subsidies) • Supplier weaknesses in market research (form associations to support market research)
Institutional frameworks	• Transaction costs • Inadequate property rights (improve land tenure) • Misplaced incentives • Distorted incentives	• Institutional structure and design (restructuring of firms) • National policy styles (shift balance of authority) • Lack of effective regulatory agencies (informal regulation)
Information provision	• Nature of information on public goods (increase public associations) • Adoption externality (build demonstration projects)	
Social, cultural, and behavioral norms and aspirations		• Inadequate consideration of human motivation and goals in climate mitigation (modify social behavior) • Individual habits (targeted advertising)

* Remarks in parenthesis indicate opportunities, e.g., missing markets denote an opportunity for the creation of markets.

Mitigation assessments should describe the requirements for removing barriers by: including information on financial requirements; assessing technology options for different mitigation options; defining the need for capacity-building to sustain mitigation work; and detailing the costs associated with the implementation of mitigation options.

VIII. MODELING TOOLS FOR MITIGATION ASSESSMENT

The modeling of mitigation options is a core component of a mitigation assessment. This chapter discusses the advantages, limitations, and the data and technical requirements of some commonly used modeling tools.

8.1 MODELING TOOLS FOR THE ENERGY SECTOR

A range of approaches are available for modeling the energy sector in a GHG mitigation assessment, and they can typically be divided into either top-down or bottom-up approaches. The UNFCCC guidelines for national communications do not specify which approach is most appropriate and both can yield useful insights on mitigation.

- *Top-down models* are most useful for studying broad macroeconomic and fiscal policies for mitigation, such as carbon or other environmental taxes.
- *Bottom-up models* are most useful for studying options that have specific sectoral and technological implications.

The lack of off-the-shelf top-down models and the focus in mitigation assessments on identifying potential projects (e.g. for future clean development mechanism (CDM) funding) has meant that, to date, most mitigation assessments have been conducted using bottom-up approaches. For this reason, the tools examined here are primarily bottom-up modeling approaches.

8.2 TYPES OF BOTTOM-UP MODELS

Bottom-up models comprise three basic types: optimization, simulation and accounting frameworks. There are various hybrid models that combine elements of these three approaches.

8.2.1 OPTIMIZATION MODELS

- Use mathematical programming to identify configurations of energy systems that minimize the total cost of providing energy services;
- Select technologies based on their relative costs;
- Assume that the cost of providing an energy service is the only factor affecting technology choice;
- Are especially useful where complex technical options need to be analysed and costs are well known;
- Tend to be data intensive and complex, and are, therefore, harder to apply when only limited expertise is available;
- Examples include: MARKAL and TIMES (see CHAPTER VIII.3.2).

8.2.2 SIMULATION MODELS

- Simulate the behaviour of energy consumers and producers under various signals (e.g. price, income levels) and constraints (e.g. limits on the rate of stock replacement);
- Can include non-price factors in an analysis compared with optimizing models;
- Balance demand and supply by calculating market-clearing prices;
- Adjust prices and quantities endogenously, using iterative calculations to seek equilibrium prices;
- Example: ENPEP-BALANCE (see CHAPTER VIII.3.1).

8.2.3 ACCOUNTING FRAMEWORKS

- Account for flows of energy in a system based on simple engineering relationships (e.g. conservation of energy);
- Account explicitly for the outcomes of decisions made by energy consumers and producers, rather than simulate their decisions;
- Tend to be simple, transparent, intuitive and easy to parameterize;
- Serve primarily as a sophisticated calculator, database and reporting tool (the evaluation and comparison of policies are largely performed externally by the analyst);
- Examples include: LEAP (see CHAPTER VIII.3.3) and RETScreen (see CHAPTER VIII.3.4).

8.3 REVIEW OF SELECTED MODELING TOOLS

This section includes an overview of four popular tools that can be used in an energy-sector GHG mitigation assessment. All the tools reviewed here:

- Have been widely applied in a number of international settings;

- Have been thoroughly tested and generally found to be credible;
- Are being actively developed and professionally supported;
- Are Microsoft Windows based tools with user-friendly interfaces for data entry and reporting.

The four tools are:

- *The Energy and Power Evaluation Programme (ENPEP)*, developed by the Argonne National Laboratory and the International Atomic Energy Agency (IAEA);
- *The Long-range Energy Alternatives Planning system (LEAP)*, developed by the Stockholm Environment Institute;
- *The Market Allocation Model (MARKAL) and its successor TIMES (The Integrated MARKAL EFOM system)*, developed by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA);
- *The Renewable Energy and Energy-efficient Technologies Screening system (RETScreen),* developed by Natural Resources Canada.

All of the above are integrated scenario modeling tools except for RETScreen, which screens renewable and other energy technologies and its scope therefore complements the other tools reviewed here.

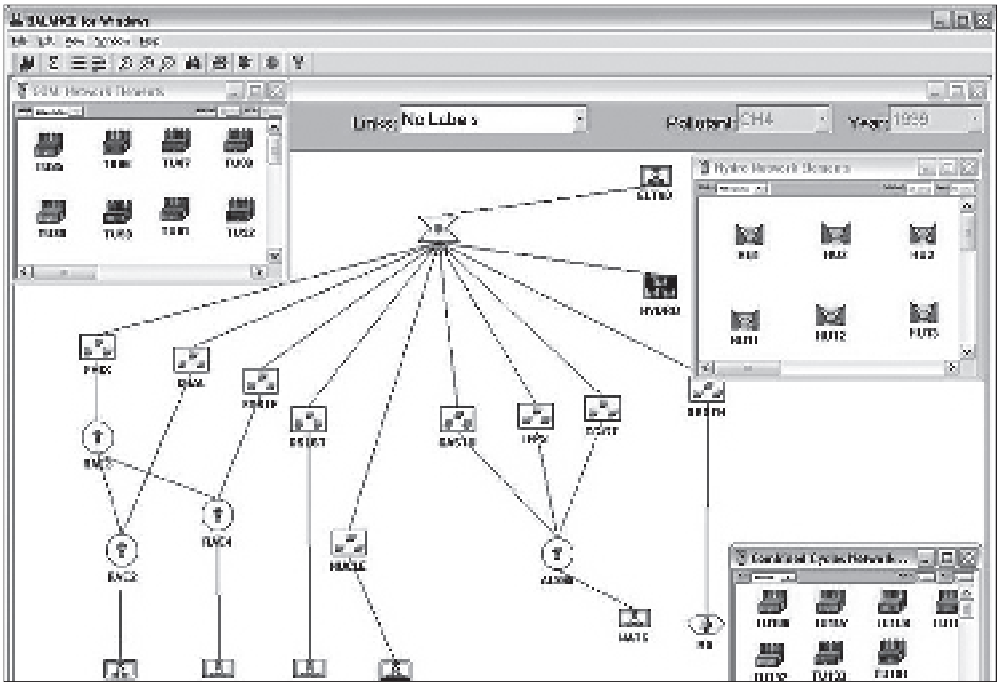
These tools are available under various licensing conditions depending on the status of the organization using the tool. Please refer to the website for each tool for its licensing conditions.

8.3.1 ENPEP

ENPEP comprises a set of ten integrated energy, environmental, and economic analysis tools. Its component BALANCE is particularly useful for GHG mitigation assessment. Unlike an optimization model such as MARKAL, ENPEP does not minimize costs. Instead, it predicts the response of consumers and producers by simulating a market clearing equilibrium for prices and quantities.

For more information visit the website, <http://www.dis.anl.gov/projects/Enpepwin.html>

Figure VIII-5. **ENPEP-BALANCE**



8.3.2 MARKAL AND TIMES

MARKAL identifies least-cost solutions for energy-system planning by selecting technologies based on life-cycle costs of alternatives. It generates energy, economic, engineering, and environmental equilibrium models. The models are represented as Reference Energy Systems (RES), depicting an entire energy system from resource extraction, through energy transformation and end-use devices, to the demand for useful energy services.

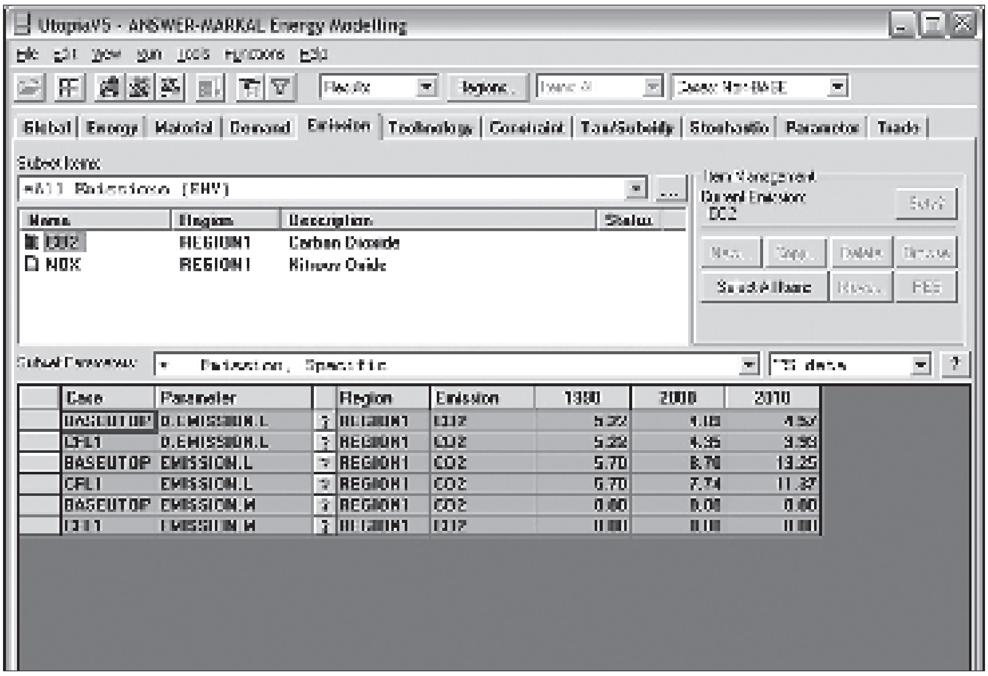
MARKAL calculates the quantity and price of each commodity, in order to maximize either the utility (MARKAL-MACRO) or the producer/consumer surplus (MARKAL) over the planning horizon and thereby minimize the total energy-system cost.

MARKAL-MACRO is an extension of the MARKAL system that simultaneously models both energy and economic systems. It can be viewed as a hybrid model as it merges elements of both top-down and bottom-up analyses.

TIMES is a new tool that is gradually expected to replace MARKAL.

For more information visit the website, <http://www.etsap.org>

Figure VIII-6. **MARKAL**



8.3.3 LEAP

LEAP is an integrated energy-environment, scenario-based modeling system, which uses relatively simple accounting and simulation modeling approaches.

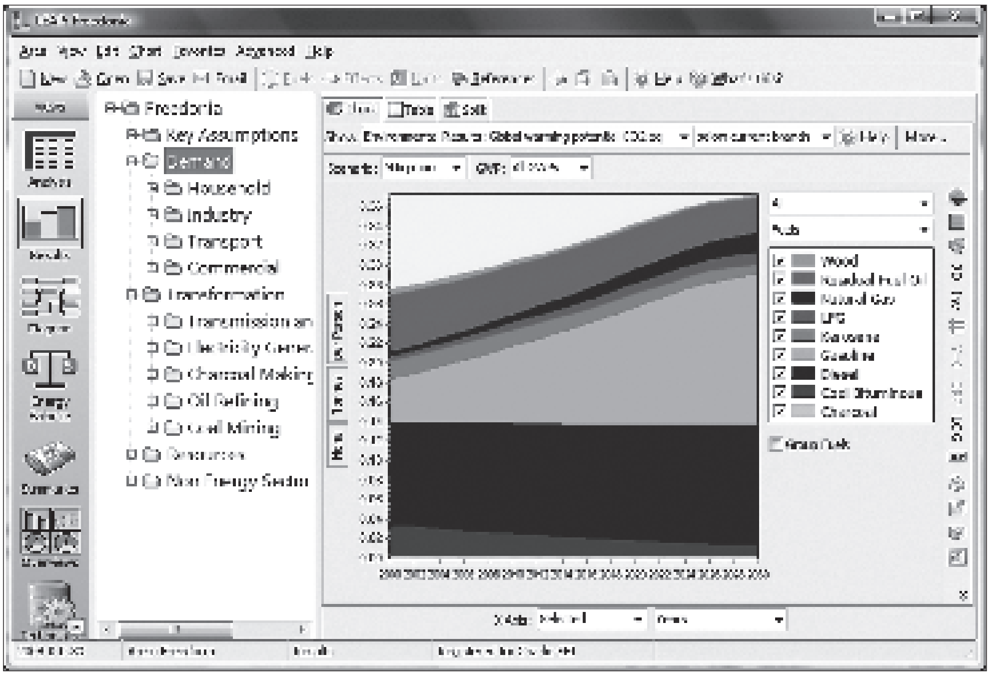
With LEAP, users can create models covering energy demand, transformation and resource extraction as well as emissions of GHGs and local air pollutants from both the energy and non-energy sectors. LEAP can also be used to analyse social cost-benefit of energy systems.

While its methodology is more simple than that of MARKAL and ENPEP, LEAP has lower initial data requirements than the other two models and is also more user-friendly for those with limited experience of energy and GHG modeling. LEAP also emphasizes other aspects of mitigation assessment by providing flexible and intuitive data management and advanced reporting capabilities.

The developers of LEAP are currently developing national-level LEAP data sets for use by Parties undertaking mitigation assessments. These data sets will provide a starting point for mitigation assessments, and will include: historical demographic, economic, energy and emissions data; baseline projections of energy consumption, production and emissions of all major greenhouse gases; and a suggested structure for undertaking a national mitigation assessment. These data sets will be available from the LEAP website (by late 2008) and will be distributed at no charge to qualifying organizations in developing countries.

For more information visit the website, <http://www.energycommunity.org>

Figure VIII-7. **LEAP**



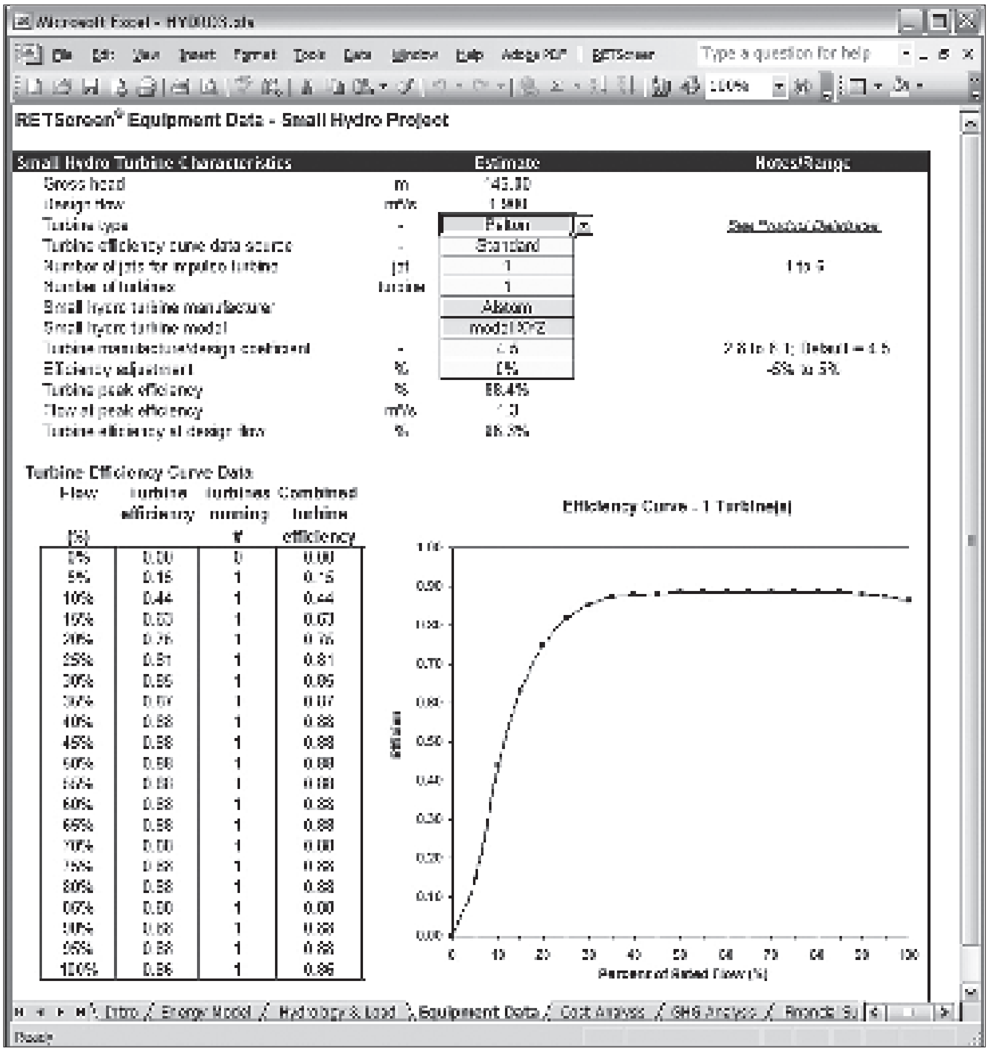
8.3.4 RETSCREEN

Unlike the other three tools that have been discussed, which are all integrated models of a complete energy system, RETScreen is structured as a collection of more specialized spreadsheet-based tools, each of which can be used for screening potential options *before* they are included in integrated mitigation assessments. RETScreen therefore complements the other tools by helping to develop the technical, cost and performance variables required in other models.

RETScreen can be used to assess the energy production, life-cycle costs and GHG emissions reductions from a wide range of Renewable-energy and Energy-efficient Technologies (RETs), including wind, solar hot water, solar photovoltaic, combined heat and power, small hydro, biomass and ground-source heat pump technologies, as well as other energy-efficiency measures.

For more information visit the website <http://www.retscreen.net>

Figure VIII-8. RETScreen



8.4 MODELING TOOLS FOR THE NON-ENERGY SECTORS

A wide variety of modeling methods can be used to examine mitigation in non-energy sectors. The majority of these models focus on issues of land use, land-use change and forestry (LULUCF). Many alternative models and modeling approaches have been developed for examining LULUCF mitigation, including:

- Individual tree growth models;
- Forest gap models;
- Bio-geographical models;
- Ecosystem process models;
- Terrestrial carbon-circulation models;
- Land-use change models;
- Spreadsheet models

Notable models that have been applied in these areas include:

- *IMAGE* (Integrated Model to Assess the Global Environment), developed at the National Institute for Public Health and the Environment (RIVM) in the Netherlands. For more information on IMAGE, visit the website http://www.mnp.nl/en/themasites/image/index.htm

- *COMAP* (Comprehensive Mitigation Assessment Process), a spreadsheet-based model developed by the Lawrence Berkeley Laboratory in the USA. For more information on COMAP, visit the website http://ies.lbl.gov/iespubs/iesgpubs.html

A wide array of additional models is available for modeling mitigation in the LULUCF sector. Unfortunately, unlike the tools listed for the energy sector, these tools are not normally professionally developed, distributed and supported, and it is therefore more difficult to get access to them and support when using them. The University of Kassel maintains a web-based Register of Ecological Models (REM), which is a useful resource for reviewing many of these tools. REM is available here: <http://eco.wiz.uni-kassel.de/ecobas.html>

KEY STEPS IN A LULUCF ASSESSMENT

1. Identification and categorization of mitigation options;
2. Assessment of current and future land area available for mitigation options;
3. Assessment of current and future demand for products and land;
4. Determination of the land area and product scenarios by mitigation option;
5. Estimation of the carbon sequestration per hectare for major available land classes, by mitigation option;
6. Estimation of unit costs and benefits;
7. Evaluation of cost-effectiveness indicators;
8. Development of future carbon sequestration and cost scenarios;
9. Exploration of policies, institutional arrangements and incentives necessary for the implementation of mitigation options;
10. Estimation of the national macro-economic effects of these scenarios.

IX. REPORTING MITIGATION IN NATIONAL COMMUNICATIONS

Mitigation assessments form an important part of Parties' national communications to the UNFCCC. They are read by the international scientific community, as well as national and international policy makers. Therefore, they need both a high level of scientific rigour and a high level of clarity and comprehensibility. Information on any mitigation projects that have been implemented or proposed could include information on sources of funding provided by multilateral and bilateral programmes. For more details on the UNFCCC reporting requirements, see CHAPTER IV.2.

9.1 SUGGESTIONS FOR REPORTING

To ensure clarity and readability of the assessment, the following should be taken into consideration:

Presentation of Information:

- A summary should present the main findings across energy and non-energy sectors;
- Typically, energy and non-energy sectors can each be reported upon separately;
- Reporting should follow international scientific practices for documentation and referencing of data sources;
- Results can be shown in chart and table formats; charts should be supported by numeric tables for greater clarity. All charts and numeric data should be clearly labelled with unambiguously specified units.

Units and Emissions Factors:

- GHG results should preferably be expressed as tonnes of carbon (tonnes C) or as tonnes of CO_2 equivalent (t CO_2 eq);
- Reports can use any unit, but a table of unit conversion factors should be included to enable a proper interpretation of results;
- Fuel consumption and production should preferably be reported in standard energy units (e.g., GJ, GWh, toe, etc.). Where physical units are used (mass, volume), the fuel's energy content and density should also be reported;
- With regard to emissions calculations, reporting should present the main emissions factors used in the assessment, describe the assumptions that were used concerning GWP and if non-GHG gases were examined, and describe how they were assessed.

Underlying Assumptions and Parameters:
In addition to presenting results, reports should describe the assumptions made, the methods adopted, and the sources of data used:

- *Methodology:* Reporting should describe which modeling methodology was adopted and why, how the structure of the national energy system was reflected in the model, and which disaggregation structure was used and why;
- *Scenarios:* Reporting should also describe the scenarios that were examined, any sensitivity analyses that were conducted, and how the baseline scenario was defined;
- If possible, any uncertainties associated with findings should be discussed.

9.2 TYPES OF RESULTS TO INCLUDE IN REPORTS

The types of results that might be incorporated in a national communication include:

- *Screening.* The national communication should discuss and illustrate the process used for screening technology options;
- GHG emissions for the baseline and mitigation scenarios should be disaggregated by sector, by fuel and by gas in each scenario. If GHGs other than CO_2 are considered, the results should be presented as CO_2 equivalents. Reporting, if it is included in the study, should also show results for emissions of other local air pollutants (e.g. SO_x, NO_x particulates, etc.);
- *"Jaws" charts* (see FIGURE IX-9). These charts help to illustrate GHG savings from the various measures constituting an overall mitigation scenario. The top line of the chart shows baseline emissions and each lower line shows the savings resulting from adding another measure (plotted over time, this reveals a set of open "jaws"). The lowest line is the combined mitigation scenario.

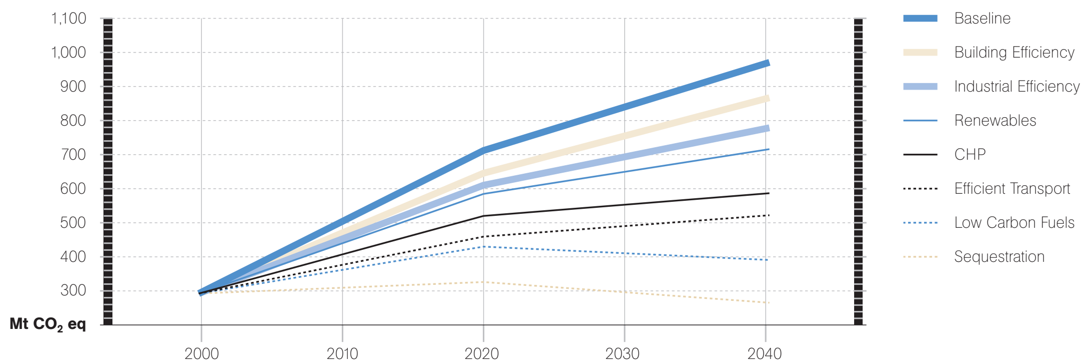
- Other possible results, such as: national energy balances, cost curves, cost summaries, primary and final energy consumption, by fuel and by sector or subsector; final energy intensities (e.g. energy per capita or per unit of GDP); major results for energy supply sectors such as electric generation, transmission and distribution and oil refining; and imports and exports of major fuels, where appropriate.

9.3 PREPARATION OF FUTURE NATIONAL COMMUNICATIONS

National communications should build on the efforts and experiences detailed in previous communications. A stocktaking exercise can be useful for identifying gaps and areas for further study; it can help, for example, with:

- *Gaps* (what studies or assessments are needed to improve information or fill gaps in knowledge?);
- *Uncertainties* (how can the reliability of information be increased?);
- *New areas of work* (what areas were not included in the national communication submitted?);
- *Priorities* (how can they help to focus on priority areas for the next national communication?).

Figure IX-9. **An example of a jaw chart**



X. REFERENCES AND RESOURCES

BENIOFF R. AND WARREN J. (EDS) 1996. *Steps in Preparing Climate Change Action Plans: A Handbook.* Washington DC: US Country Studies Program.

CLINE W.R. 1992. *The Economics of Global Warming*. Washington: Institute for International Economics.

Geophysical Research Letters. 2008. *When Can We Expect Extremely High Surface Temperatures?* Available online: <http://www.agu.org/journals/gl/gl0814/2008GL034071/>

HALSNAES K., CALLAWAY J.M. AND MEYER H.J. 1999. *Economics of Greenhouse Gas Limitations: Methodological Guidelines*. UNEP Collaborating Centre on Energy and Environment, Denmark. Available online: <http://uneprisoe.org/EconomicsGHG>

HEAPS, C. 2008. *User Guide for LEAP, the Long range Energy Alternatives Planning System*. Stockholm Environment Institute, Sweden. Available online: <http://www.energycommunity.org/default.asp?action=41>

HEAPS, C. 2008. *Training Exercises for Greenhouse Gas Mitigation Assessment Using LEAP*. Stockholm Environment Institute, Sweden. Available online: <http://www.energycommunity.org/default.asp?action=42>

IPCC. 1996. *Technologies, Policies and Measures for Mitigating Climate Change*. Watson, R.T.; Zinyowera, M.C.; Moss, R.H. (EDS). Available online: <http://www.ipcc.ch/pub/techrep.htm>

IPCC. 2000. *Emissions Scenarios. Special Report of the Intergovernmental Panel on Climate Change*. Available online: <http://www.ipcc.ch/ipccreports/index.htm>

IPCC. 2000. *Methodological and Technological Issues in Technology Transfer*. Cambridge University Press. Available online: <http://www.ipcc.ch/ipccreports/index.htm>

IPCC. 2001. *Climate Change 2001: Mitigation. Working Group III Contribution to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Available online in Arabic, Chinese, English, French, Spanish and Russian: <http://www.ipcc.ch/ipccreports/index.htm>

IPCC. 2007. *Climate Change 2007: The Physical Science Basis. Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Available online: <http://www.ipcc.ch/ipccreports/ar4-wg1.htm>

IPCC. 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Available online in Arabic, Chinese, English, French, Spanish and Russian: <http://www.ipcc.ch/ipccreports/index.htm>

IPCC. 2007. *Climate Change 2007: Mitigation of Climate Change. Working Group III Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC Assessment Reports are available online in Arabic, Chinese, English, French, Spanish and Russian: <http://www.ipcc.ch/ipccreports/index.htm>

KLEIN ET AL. 2003. *Integrating Mitigation and Adaptation into Climate and Development Policy: Three Research Questions.* Tyndall Centre Working Paper No. 40. Available online: <http://www.tyndall.ac.uk/publications/working_papers/wp40_summary.shtml>

LINDEN ET AL. 1999. *Potential and Cost of Clean Development Mechanism Options in the Energy Sector: Inventory of Options in Non-Annex I Countries to Reduce GHG Emissions*. ECN-C–99-095, Petten. Available online: <http://www.ecn.nl/docs/library/report/1999/c99095.pdf>

NORDHAUS W.D. 1994. *Managing the Global Commons.* Cambridge, Massachusetts: MIT Press.

NORDHAUS W.D. AND BOYER J. 2000. *Warming the World.* Cambridge, Massachusetts: MIT Press.

OECD/IPCC. 2000. *Ancillary Benefits and Costs of GHG Mitigation.* Can be accessed at: <http://www.oecd.org>

Proceeding of the National Academies of Science. 2008. *Proxy-Based Reconstructions of Hemispheric and Global Surface Temperature Variations over the Past Two Millennia.* Available online: <http://www.pnas.org/content/early/2008/09/02/0805721105.full.pdf>

Repetto R. and Austin D. 1997. *The Costs of Climate Protection: a Guide for the Perplexed.* WRI. Available online: <http://pubs.wri.org/pubs_description.cfm?PubID=2475>

Sathaye J. and Meyers S. 1995. *Greenhouse Gas Mitigation Assessment: A Guidebook.* Netherlands: Kluwer Academic Publishers. Available online (excluding tables and charts): <http://ies.lbl.gov/iespubs/iesgpubs.html>

Sperling D. and Salon D. 2002. *Transportation in Developing Countries: An Overview of Greenhouse Gas Reduction Strategies.* Pew Center on Global Climate Change. Available online: <http://www.pewclimate.org/docUploads/transportation_overview.pdf>

Stern, N. 2007. *The Economics of Climate Change: The Stern Review.* Cambridge, UK: Cambridge University Press.

UNDP. 2000. *World Energy Assessment: Energy and the Challenge of Sustainability.* Goldemberg J. (ed.). United Nations Development Programme: United Nations Department of Economic and Social Affairs, World Energy Council. Available online: <http://www.undp.org/energy/weaover2004.htm>

UNFCCC. 2004. *User Manual for the Guidelines on National Communications from non-Annex I Parties*. Available online in English, French and Spanish <http://unfccc.int/national_reports/non-annex_i_natcom/guidelines_and_user_manual/ items/2607.php>

For a number of additional online resources that are useful for energy sector mitigation assessment, please refer to the online library of resources made available at the COMMEND community web site: <http://www.energycommunity.org/default.asp?action=73>

This publication is issued for public information purposes and is not an official text of the Convention in any legal or technical sense. Unless otherwise noted all material may be freely reproduced in part or in full, provided the source is acknowledged.

For further information contact

Climate Change Secretariat (UNFCCC)
Martin-Luther-King-Strasse 8
53175 Bonn, Germany

Telephone +49. 228. 815 10 00
Telefax +49. 228. 815 19 99

Email secretariat@unfccc.int
www.unfccc.int

Produced by the Financial and Technical Support Programme of the UNFCCC

Art direction and design: Heller & C
Printing: Color Gruppe, Munich
Paper: Classen-Papier Z-Script*

* Recycled paper

Produced by the Financial and Technical Support Programme of the UNFCCC.

United Nations Framework Convention on Climate Change