UNEP

A simplified guide to the IPCC's "Climate Change 2001: Mitigation"

What do we know about reducing greenhouse gas emissions?

This guide has been funded and produced by the United Nations Environment Programme with additional support from the Government of the Netherlands. For more information, please contact UNEP, Information Unit for Conventions, International Environment House, 15 chemin des Anémones, CH-1219 Châtelaine (Geneva), Switzerland; iuc@unep.ch; or +41-22-917-8244/8196. See also www.ipcc.ch, www.unep.org, and www.wmo.ch.

All figures in this booklet are from ***"Climate Change 2001: Mitigation"***, Intergovernmental Panel on Climate Change, Cambridge University Press, 2001.

GE.0201807/E - September 2002 - 2000

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Foreword

The concepts and conclusions presented by "Climate Change 2001: Mitigation", part of the ground-breaking Third Assessment Report by the WMO/UNEP Intergovernmental Panel on Climate Change, are central to global action on climate change. While the first two volumes of the Report detail what is known about causes, impacts, and adaptation – thus highlighting the need for action – the third volume on mitigation analyses how to take action by limiting net greenhouse gas emissions. Policymakers at the national and local levels, business leaders, community leaders, and concerned individuals and organizations can use these tools to make a real difference.

This simplified guide briefly introduces and explains what Working Group Three – led by its co-chairs, Prof. Ogunlade Davidson of Sierra Leone and Dr. Bert Metz of The Netherlands – found when it assessed the peer-reviewed expert literature on mitigation. The guide is not an official document and has been neither approved nor accepted by the IPCC. Instead, it represents an effort to make the hundreds of pages of detailed and technical text that constitute the volume on "Mitigation" more accessible to a broader audience. It is my sincere hope that you will find this introduction useful in its own right and that it will serve as a stepping stone to further understanding and action.

Klaus Töpfer
Executive Director
United Nations Environment Programme

About the IPCC

The Intergovernmental Panel on Climate Change was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The IPCC does not conduct new research. Instead, its mandate is to make policy-relevant assessments of the existing world-wide literature on the scientific, technical and socio-economic aspects of climate change. Most of this expert literature has appeared in peer-reviewed publications.

The IPCC has produced a series of assessment reports, special reports, technical papers and methodologies that have become standard works of reference for climate change policymakers, experts, and students. The Panel is organized into three Working Groups: Working Group I focuses on the science of the climate system; Working Group II on impacts, vulnerability and adaptation; and Working Group III on mitigation, a term used to describe human interventions to reduce greenhouse gas emissions and to enhance "sinks" (forests, oceans and other natural systems that can absorb carbon dioxide from the atmosphere and store it).

The IPCC's First Assessment Report was completed in 1990 and helped to inspire the intergovernmental talks that led to the 1992 United Nations Framework Convention on Climate Change. Its Second Assessment Report was published in 1996 and played a role in the Kyoto Protocol negotiations. The 2001 Third Assessment Report concentrated on new findings since 1995 and paid special attention to what is known about climate change at the regional level.

Introduction

Human activities such as industry and agriculture are emitting carbon dioxide, methane and other greenhouse gases that change the way the atmosphere absorbs and re-emits energy. According to current projections, higher atmospheric concentrations of these gases will cause the average global temperature to rise by 1.4 to 5.8°C by the year 2100. This warming would be much larger and much more rapid than any temperature change experienced over at least the last 10,000 years. It would have significant impacts on human society and the natural environment.

Climate change will affect our future ability to satisfy human needs, in both positive and negative ways. It will alter agricultural conditions; local and regional trends in droughts, floods, and storms; stresses on buildings and other long-standing infrastructure; health risks; and much more. Many environmental changes that are consistent with global warming can already be detected today.

Some degree of climate change is now inevitable due to past emissions. One essential strategy for responding to this will be adaptation, which involves taking action to help communities and ecosystems cope with changing climate conditions.

The second strategy, known as mitigation, is based on action to limit net emissions of greenhouse gases – defined as emissions minus removals by sinks (such as forests). Limiting emissions will slow and eventually reverse the rise in atmospheric concentrations of greenhouse gases. (Because greenhouse gases remain in the atmosphere for decades or longer, atmospheric levels respond only gradually to lower emissions.) In this way, mitigation can minimize climate change and its expected negative impacts.

The 185 member governments of the UN Climate Change Convention have agreed that their objective is to stabilize atmospheric concentrations of greenhouse gases at safe levels. How can this goal best be achieved? What are the most promising policies and technologies? What are their costs and benefits? What are the barriers to adopting them? And how can action on climate change be made mutually supportive with sustainable development? This booklet will explore the IPCC's answers to these questions.

What is the mitigation challenge?

Climate change is a global, complex, and long-term problem (up to several centuries) that is still not fully understood.

Climate change involves complex interactions amongst climatic, environmental, economic, political, institutional, social and technological processes. While the IPCC reports reflect a broad scientific consensus on key points such as the reality of the risks involved, they also identify many uncertainties. Some of these relate to the complexity of natural systems, others to the fact that future human actions affecting climate change are as yet unknown. For example, the type, magnitude, timing and cost of mitigation depend on what is feasible – given differing national circumstances, socio-economic conditions and technologies – and on what emissions target has been agreed. The end result is that governments must take decisions on climate change under circumstances characterised by uncertainty and risk.

Climate change is intimately linked to broader development issues.

Climate change mitigation is not a stand-alone problem: It will both affect and be affected by socio-economic policies and by choices involving development, sustainability, and equity. Policies to limit net emissions can best promote sustainable development if they are consistent with broader societal objectives. Some mitigation actions can even promote benefits far beyond immediate climate concerns – such as reducing health problems, increasing local employment, minimizing air pollution, protecting and enhancing forests and watersheds, minimizing certain subsidies and taxes, and accelerating the development and diffusion of energy-efficient technologies. Similarly, development choices that promote sustainability may result in lower emissions.

Equity concerns arise within and between countries and generations.

Equity issues are shaped by the unequal distribution of resources – technological, natural and financial – between countries and regions and between present and future generations. They reflect the ability of some countries (and generations) to reduce emissions more or less expensively than others can. Inequities are likely to be created or worsened by the impacts of climate change and of climate changes policies. Concern about equity led governments to incorporate the principle of "common but differentiated responsibilities" into the Climate Change Convention and to assign developed countries – the major emitters to date – responsibility for taking the lead on reducing emissions; developing countries have no quantitative emissions commitments but are expected to pursue development paths leading to lower emissions.

Climate-friendly energy sources are the key to cutting emissions.

Since fossil fuels are the primary source of greenhouse emissions, changing the way energy is produced and consumed will prove central to reducing emissions. Most available energy strategies involve moving away from fossil fuels and exploiting zero- or low-carbon sources. The extent to which the global energy mix evolves towards such sources will determine whether atmospheric concentrations of greenhouse gases are stabilized or reduced – and at what level and cost. Currently, most investment in energy production still goes towards discovering and developing more fossil fuel resources.

Technologies and practices

Many low-emissions technologies are available now – but they are not being fully exploited.

Global emissions could be reduced below current levels within a few decades using technologies that are already available or being tested. These existing technologies might even suffice to stabilize atmospheric concentrations of carbon dioxide (CO_2) over the next 100 years at levels well below twice pre-industrial levels (that is, well below 550 parts per million, compared to today's 365). This would require transferring these technologies to countries and regions that currently lack them. In addition, many barriers to fully exploiting low-emissions technologies will have to be overcome.

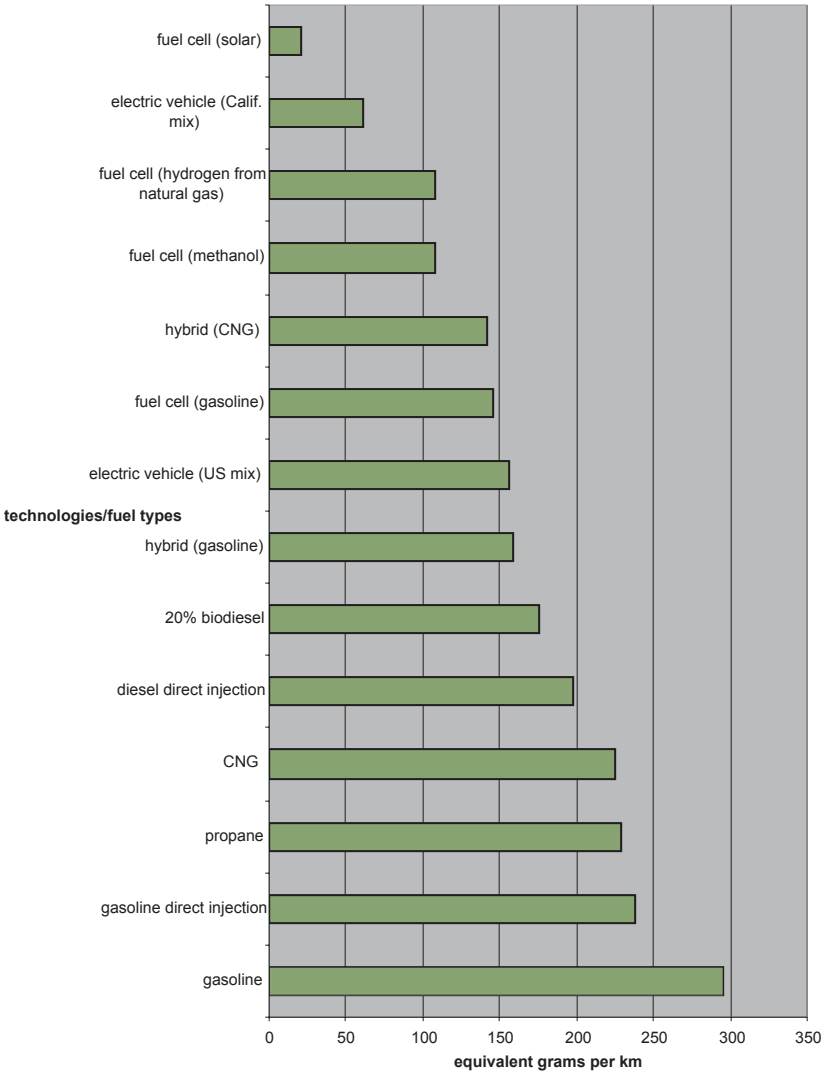
All economic sectors have seen a faster-than-expected development of climate-friendly technologies over the past decade.

While it is essential that all sectors exploit new these technologies, two sectors of particular importance will be illustrated below. The first is energy and industry, which includes energy production plus energy use in transport, industry and buildings. Many technologies and practices involving conservation, increased fuel efficiency and alternative fuels are available for reducing energy-related emissions. The second key sector is agriculture and forestry. Here the main potential is for storing carbon in sinks and reducing emissions of methane and nitrous oxide through improved land management.

All sectors can pursue energy conservation and efficiency improvements.

Hundreds of technologies and practices exist for converting fossil fuels into energy more efficiently, thus reducing greenhouse gas emissions from households, infrastructure, transport, and industry. For example, combined-cycle gas turbines – in which the heat from the burning fuel drives steam turbines while the thermal expansion of the exhaust gases drives gas turbines – may boost the efficiency of power generation by 70%; in the longer term, new technologies could double the efficiency of power plants. Meanwhile, fuel cells and other advanced automotive technologies can reduce emissions from transport (see Figure 1).

Figure 1. Greenhouse gas emissions from advanced automotive technologies and alternative fuels.



Note: The various greenhouse gases are translated into "CO_2 equivalents" that are then added up to produce a single figure.

Industry's main short-term option is to enhance energy efficiency.

Industry accounts for over 40% of global carbon dioxide emissions, and its energy efficiency varies widely from country to country. Short-term improvements may come from combined heat and power co-generation, other uses of waste-heat, improved energy management, and innovations in manufacturing processes. Improving material efficiency through better product design, recycling, and material substitution can also reduce emissions. Energy efficiency improvements will remain important for industry over the longer term as well.

There are many options for moving to cleaner energy sources.

One of the sources promising fewer emissions per unit of energy is natural gas, which, though a fossil fuel, releases less CO_2 than coal or oil. Various forms of renewable energy can also cut emissions. These include biomass sources, such as fuelwood, alcohol fermented from sugar, combustible oils extracted from soy beans, and methane gas emitted by waste dumps. These sources will contribute to emissions reductions if they are sustainably produced, for example through regular replanting. Where suitable land and water is available, crops grown as biomass fuels can supplement naturally existing biomass sources.

Other low- and zero-emissions renewables include hydroelectricity, solar photovoltaics, wind energy and hydrogen fuel cells. While large-scale hydropower could make a significant contribution to reducing emissions, its use may be limited by concerns about its impacts on human settlements and river systems. The use of non-hydro renewables continues to grow as their costs decline, although their contribution to global energy supplies is currently still below 2%.

Nuclear energy also emits virtually no greenhouse gases. However, it faces public concerns over safety, the transport and disposal of radioactive wastes, and weapons proliferation.

Meanwhile, new technologies have become available that can capture carbon dioxide emitted by fossil-fuel power plants before it reaches the atmosphere. This could offer a cost-competitive "clean fossil" energy alternative to renewables. The captured carbon dioxide would be stored underground, in empty oil or gas reservoirs, underground water reservoirs, unused coal beds or in the deep ocean. Some such applications are already in operation. However, more research is needed on reducing the costs and assessing the possible risks and environmental impacts.

Enhancing carbon sinks can partially offset fossil fuel emissions.

As trees grow, they store carbon, thus keeping it out of the atmosphere (see Figure 2).

Sinks can therefore buy time for developing low-emitting technologies. This can be achieved by:

1. conserving existing carbon sinks, for example by slowing or halting deforestation;
2. expanding the size of carbon sinks, for example by planting trees or enhancing the ability of soil to retain carbon; and
3. substituting sustainably-produced biological products for fossil fuels and fossil-fuel-based products, for example by using biomass fuels instead of coal or oil for energy, or wood instead of steel for construction.If properly managed, forest and soil sinks may provide social, economic and environmental benefits beyond reducing atmospheric carbon dioxide. Healthy forests that absorb CO_2 can also conserve nature, prevent erosion, and create rural employment. If poorly managed, forests and soils can cease storing CO_2, lose biodiversity, pollute groundwater and disrupt local communities.

Even if the amount of carbon stored in trees, vegetation and soils increases, there remains a risk that CO_2 will be released in the future if the underlying ecosystem is later disturbed by fire, land clearance or other natural or human-induced changes. Appropriate, long-term land management in areas where carbon is stored is therefore essential.

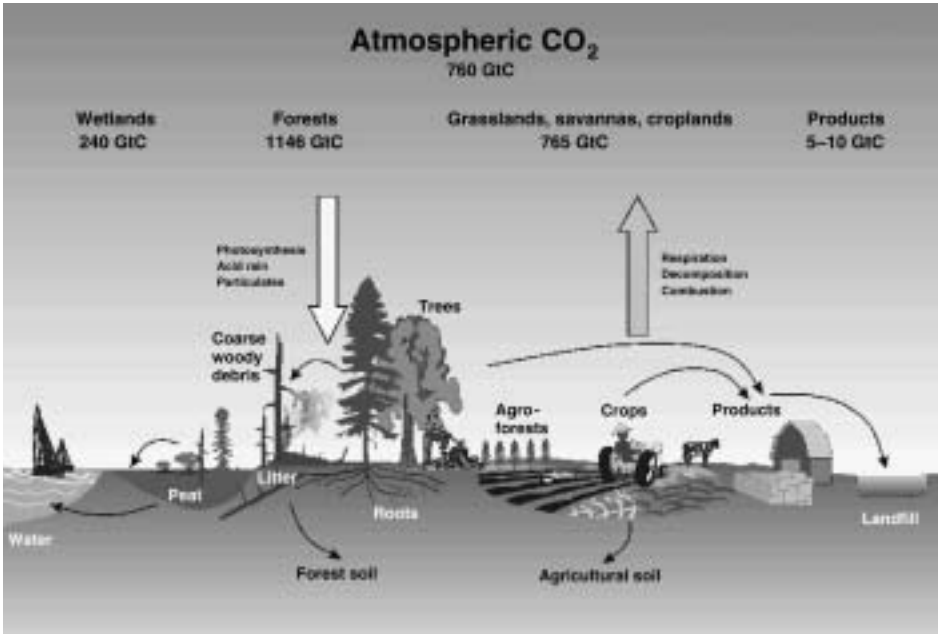
Conserving threatened forests may not offset emissions if it simply displaces tree cutting or clearing to other areas. To be sustainable, a strategy for enhancing sinks must address the broader socio-economic causes of deforestation and other activities that destroy carbon sinks.

Improved agricultural management can boost carbon storage.

Carbon stored in agricultural soils can often be preserved or enhanced through no-tillage or low-tillage techniques, which slow the rate at which organic soil matter decomposes. Changing how a parcel of land is used, for example from cropland to grassland, to better suit its soil characteristics, can also contribute. The introduction of nitrogen-fixing legumes in grazing land favours carbon storage. Reducing erosion through terracing, windbreaks, and residue management can further prevent losses of carbon (as well as nitrogen). However, the net effect of soil erosion on carbon storage is still uncertain, because the carbon in eroded soil may simply be deposited in soil elsewhere and become at least partially stabilized.

In rice fields, methane emissions can be suppressed to some extent through tillage practices, water management, and crop rotation. In general, using nitrogen fertilizers more efficiently can reduce emissions of nitrous oxide, which is a powerful greenhouse gas.

Figure 2. Carbon stocks and flows.



Different ecosystems, their components, and human activities. The carbon stocks associated with the different ecosystems are stored in aboveground and belowground biomass, dead organic matter, and soils. Carbon is withdrawn from the atmosphere through photosynthesis (vertical down arrow), and returned by oxidation processes that include plant respiration, decomposition, and combustion (vertical up arrow). Carbon is also transferred within ecosystems and to other locations (horizontal arrows). Both natural processes and human activities affect carbon flows. Mitigation activities directed at one ecosystem component generally have additional effects influencing carbon accumulation in, or loss from, other components.

Note: GtC = Gigatonnes of Carbon; 1 G = 1,000,000,000 tonnes.

Behavioural and economic changes can support technological solutions.

Climate-friendly technologies are essential for reducing emissions, but education, training, public awareness,and institutional changes can also contribute. Studies suggest that current incentive systems – based on laws, norms, taxes and other regulatory or market signals that motivate individuals or organisations to act in a particular manner – do not discourage, and may even promote, resource-intensive production and consumption patterns. New incentives could help reverse this trend and promote climate-friendly changes in lifestyles, consumption patterns and social organization. Such changes could include co-owning or renting equipment, shifting to public transport or cycling, reducing transport needs by increasing urban density and making dietary changes.

Costs and benefits

Mitigation policies can have both costs and benefits.

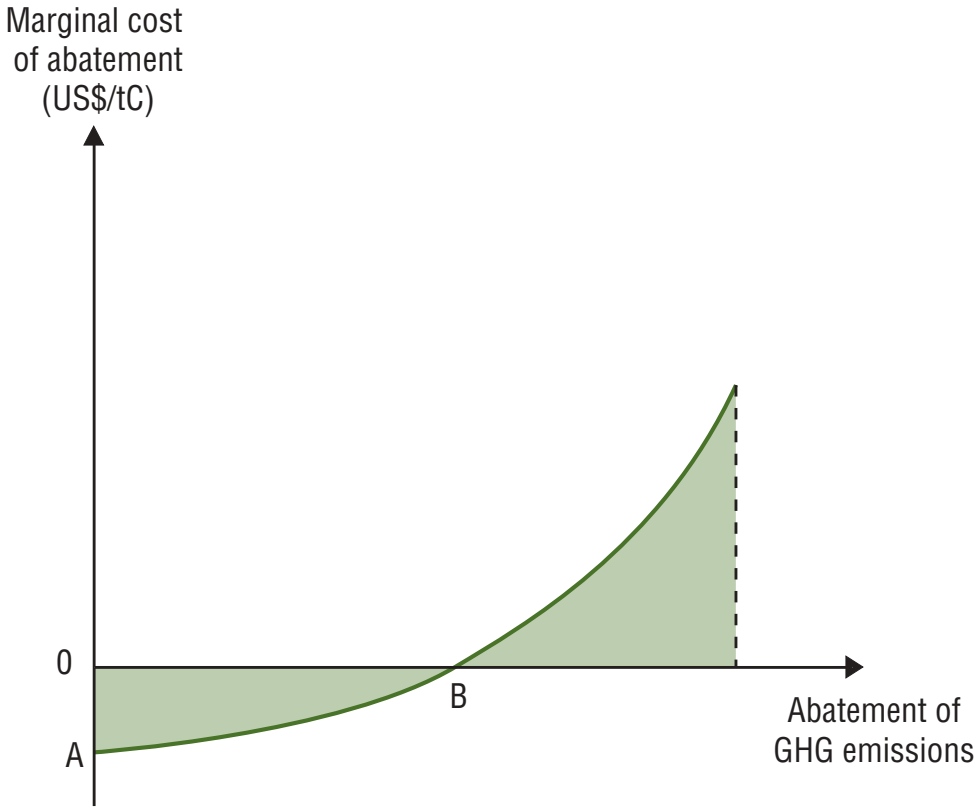
The costs of cutting emissions are likely to be relatively certain, immediate, and borne by an identifiable group. The benefits of avoided climate change, however, will be spread out over a longer period and may be difficult to put a price tag on. Many of those set to benefit are future generations and industries that do not yet exist. In addition to these direct costs and benefits, the full equation must consider the indirect effects of emissions reduction policies. These "ancillary" effects are defined as the costs and benefits of a policy over and beyond avoided climate change. Many of these effects, such as improved air quality and reduced traffic congestion, involve immediate benefits.

The costs of climate protection depend on the assumptions made.

Mitigation costs are hotly debated by economists and depend to a great degree on certain assumptions (see Figure 3):

- *the definition of the baseline*, that is, the greenhouse gas emissions that would occur in the absence of emissions policies. The baseline helps determine how expensive emissions cuts might be. It is based on assumptions about future population trends, economic growth, and technological change.
- *the discount rate*, a measure that economists use to compare future costs and benefits to current costs and benefits. A high discount rate reduces the current importance of future costs and benefits.
- *the flexibility of government regulations.* The costs of cutting emissions are often influenced by the regulations adopted by national governments to address climate change. The more flexibility allowed by the regulations, the lower the overall costs to the economy of achieving a given reduction.
- *the ancillary costs and benefits of emission reduction policies.* Climate change policies may have a number of indirect side effects – both positive and negative – on air pollution, transportation, agriculture, land-use practices, employment, and fuel security. Including these impacts in the cost equation can lead to higher or lower mitigation costs.
- *the availability of "no regret options"*, which reduce greenhouse gas emissions while generating direct or indirect (ancillary) benefits large enough to offset their costs. In some calculation methods, "no regret options" are left out. Such zero-cost options may, of course, not be sufficient by themselves to achieve an emissions target and will need to be supplemented by other measures. In addition, there may be social, economic and other barriers to their adoption.

Figure 3. A typical cost curve showing costs increasing with the level of greenhouse gas reduction.



Note: From A to B, marginal abatement costs are negative, representing no-regrets solutions. From B onwards, marginal costs are positive.

Internationally traded emissions allowances could lower costs.

Under an international system of tradable emissions allowances – such as the system established under the Kyoto Protocol – each country may emit a certain quantity of greenhouse gases each year. Countries that can reduce their emissions cheaply may sell their excess allowances to countries for which domestic action is more expensive. In this way, emissions will tend to be cut where it is least expensive to do so, lowering the overall cost. The more countries in the system, the lower costs are likely to be. In general, economists estimate that implementing the Kyoto Protocol would reduce the projected gross domestic product of the OECD (developed) countries by 0.2 – 2%. However, an emissions trading system would lower

this loss to an estimated 0.1 - 1% of future GDP. Taking into account real-world transaction costs would increase estimated GDP losses; taking into account sinks, reductions in non-CO_2 greenhouse emissions, ancillary benefits and other factors would further reduce losses.

Developed country mitigation policies could affect developing country economies.

Because the global economy is so interlinked, actions by developed countries to reduce greenhouse gas emissions have implications for developing countries known as "spill-over effects". Such effects generally lead to increased emissions in developing countries, compensating for part of the decline in developed countries. Current estimates are that full-scale implementation of the Kyoto Protocol may cause 5 - 20% of the emissions cut in developed countries to "leak" into developing countries.

For example, emissions cuts in developed countries could lower oil demand and thus international oil prices. Those countries not trying to reduce their greenhouse emissions could take advantage of the reduced price and import more oil, boosting production and thereby emitting more CO_2 than they would have otherwise. As a result, oil-importing countries may benefit economically while oil exporters see lower revenues.

Another example involves decisions to relocate carbon-intensive industries. Studies suggest that companies may respond to emissions controls in developed countries by moving some facilities to countries without such controls. Such relocation would benefit developing countries economically at the expense of developed countries. Still another example might be a decline in developing country exports if emissions controls slow economic growth in developed countries. Positive examples of spill-over exist as well; one would be the international spread of environmentally sound technologies in response to pressures to reduce emissions.

Action to reduce energy emissions can have social and economic implications.

Production and employment in the coal and oil industries would decline. The natural gas industry may or may not benefit over the next 20 years, depending on local availability, the potential for gas to replace coal in power generation, and other factors. The renewable energy sector should gain larger markets, but much depends on technological developments; in addition, the sector's prospects vary from region to region. Market gains for renewables could encourage more research and development as well as investment, leading to lower costs and even larger markets. Meanwhile, developing

country economies could benefit from opportunities to "leapfrog" to more advanced energy technologies. These countries could skip some of the steps taken by industrialized countries in their march to advanced technologies. Technology transfer could present opportunities for building up domestic expertise and institutions.

The effects on industry are likely to be mixed.

Some industries and technologies produce more value per unit of fossil fuel than do others, so they are less vulnerable to changing fuel prices; the service sector is an important example. Similarly, some sectors will be better able to adapt their production techniques to achieve lower emissions than others will, and some will find it easier to pass on any higher costs to their customers.

Firms will respond to mitigation policies by conserving energy, paying the costs of domestic controls, or shifting production to foreign countries, either as foreign direct investment or joint ventures. These actions will often create ancillary benefits, including reduced local air pollution, increased scientific and technological knowledge about climate-friendly products and processes, and technology transfer to developing regions.

Mitigation policies can improve land-use practices.

Land-based mitigation activities such as enhancing carbon sinks and producing biofuels can have a large effect on land use. If adopted on a large scale, they could promote biodiversity conservation, rural employment and watershed protection, thus contributing to sustainable development. Such benefits would be best encouraged by involving local communities and industries in designing and implementing these activities.

Barriers to action

There are many barriers to the diffusion of climate-friendly technologies.

Despite the availability of effective technologies at relatively low costs, efforts to control emissions are not very far advanced. Why is this so? The IPCC concludes that a wide range of barriers – technical, economic, political, cultural, social, behavioural and institutional – is obstructing opportunities for reducing emissions.

Institutional barriers exist to some degree in all countries.

Many countries have limited human and institutional capacity for implementing and monitoring mitigation measures. This constrains and slows down the process of adopting more efficient technologies to replace those currently in use. The lack of effective regulatory agencies is a further constraint. Many countries have excellent constitutional and legal provisions for environmental protection but they are not enforced. A further problem is limited or lacking information; businesses and consumers cannot make good decisions about which technologies to use unless they possess the appropriate information.

Cultural barriers include current lifestyles, behaviours, and consumption patterns.

Social conditions can affect consumption through, for example, the association of certain objects with status and class. The choice for more sustainable consumption patterns depends not only on the match between those patterns and the perceived needs of individuals, but also on the extent to which other consumption options are known and available.

Economic barriers send unhelpful signals to producers and consumers.

Unstable macroeconomic conditions increase general investment risks and can discourage the early adoption of environmentally sound technologies, which often have high up-front costs. Certain taxes, fossil fuel subsidies, trade barriers and other policy interventions also slow the diffusion of these technologies. Trade barriers may favour inefficient technologies or prevent access to efficient foreign technologies.

Technological barriers can exist in the early stages of a technology's introduction.

New technologies may require infrastructure that is not initially available. For example, the attractiveness of vehicles using compressed natural gas depends on the availability of convenient refuelling sites. At the same time, the development of a fuel distribution infrastructure depends on there being enough demand.

Climate-friendly policies and measures

Many different policies and measures can help to overcome barriers.

Policies and measures can be crafted to influence a broad range of economic activities or just one specific sector. Any list of possible options would likely include:

- taxes on emissions, carbon, or energy;
- subsidies for climate-friendly activities;
- deposit-refund systems for appliances, batteries and other commodities;
- voluntary agreements, notably between governments and the private sector;
- emissions trading regimes;
- regulations (such as energy-efficiency standards for buildings);
- minimum performance standards for technologies;
- bans on high-emitting products; and
- direct government investment in energy-efficient technologies.

Policies and measures should be selected only after rigorous evaluation.

Key criteria to consider include:

- *Environmental effectiveness.* How well will the policy achieve its goal of reducing emissions? How reliably will it achieve that goal? Will its effectiveness erode over time? Will it create continual incentives to improve products or processes in ways that reduce emissions? Will the policy have wider environmental effects, such as improved local air quality?
- *Cost-effectiveness.* Will the policy achieve its environmental goal at the lowest cost, taking into account transaction, information, and enforcement costs? What additional benefits will the policy or measure have?
- *Equity considerations.* How will the costs of achieving the environmental goal be distributed across groups within society, now and in the future? How will the policy affect inflation, competitiveness, employment and trade?
- *Administrative and political feasibility.* Will the policy or measure actually be implemented? Is it politically acceptable? What are the administrative requirements? Could the policy be enforced? How will it interact with other government objectives (such as meeting fiscal targets)? Will it contribute to changing attitudes and increasing awareness of climate change?

Because the importance of these criteria will differ according to time and place, most governments will limit net emissions through a portfolio of policy instruments, rather than a single policy. In this way, policymakers can combine the strengths of various policy instruments while compensating for their weaknesses, thus improving overall effectiveness and efficiency.

Countries may benefit from coordinating their policies and measures.

Coordinating action among countries and sectors could help address concerns about competitiveness and potential conflicts with international trade rules. It could also reduce costs. Some options are:

- the Kyoto Protocol mechanisms, namely joint implementation (JI), the clean development mechanism (CDM) and international emissions trading;
- an international tax on emissions, carbon, or energy;
- internationally coordinated product standards; and
- international voluntary agreements.

Non-climate policies can also affect greenhouse gas emissions.

Examples include trade liberalization, price and subsidy reforms and the opening of energy markets. Such macroeconomic policies can create favourable conditions for promoting climate-friendly investments.

Towards sustainable development

Environment and development issues are strongly interlinked.

Climate change, biodiversity, desertification, freshwater supplies, forests and poverty are linked through a complex set of physical, chemical, and biological processes (see Figure 4). Climate change, for example, alters the global hydrological cycle, affects the functioning of ecological systems, and accelerates land degradation and desertification. These negative impacts can reinforce each other and seriously threaten land productivity, food, freshwater supplies, and biological diversity. Policies addressing climate change can thus ameliorate other problems. They can also involve trade-offs, however. For example, depending on how it is managed, large-scale tree planting aimed at sequestering carbon could negatively affect local biodiversity and local development opportunities.

Treaties on environment and sustainable development share common goals and means.

The international community is addressing environment and sustainable development through a range of binding and non-binding agreements. These agreements – the desertification, biodiversity, climate change and ozone treaties, for example – tend to interact at many levels. They also share many common features, requiring their members to:

- build governmental and civil institutions to implement internationally agreed actions;
- formulate strategies and action plans as a framework for country-level implementation;
- collect data and report on their obligations; and
- strengthen the capacity of both human resources and institutions.

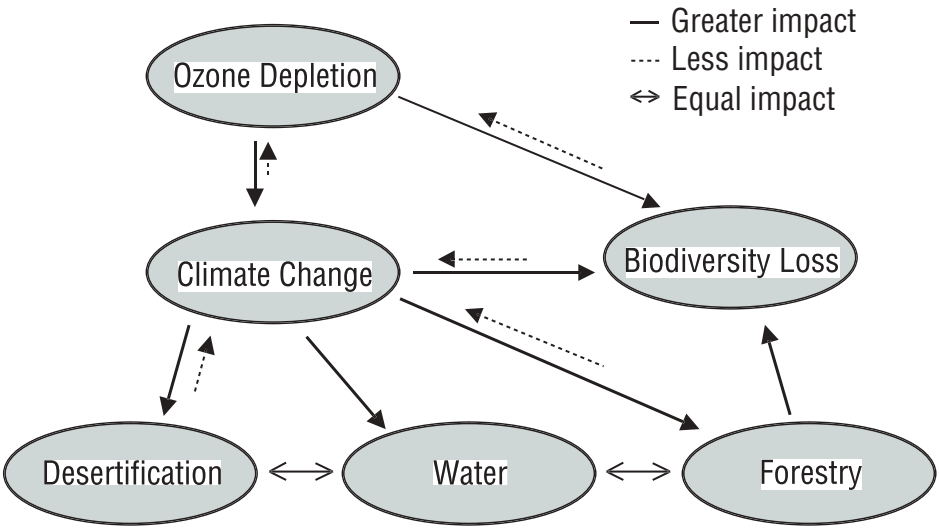
Coordinating the implementation of these agreements at the local, national and international levels can reinforce their effectiveness and avoid duplication of effort.

National policies can ensure that climate change and sustainable development goals are mutually reinforcing.

Policies for limiting emissions can be more effective when they take development issues into account. Conversely, non-climate policies can produce climate benefits.

Recognizing the potential for synergies between climate and development can lower the political and institutional barriers for climate-specific measures. Many synergies can be found in actions related to industry, transportation, agriculture, forestry, and human settlements.

Figure 4. Linkages among environmental issues.



For example, decentralized development patterns based on a stronger role for small- and medium-sized cities can slow the rural exodus and reduce transport needs. They can also encourage solar energy, small-scale hydropower and other technologies that enable communities to tap their natural resources sustainably. Similarly, adopting environmentally sound technologies for both energy production and energy consumption can reduce public investments, improve export competitiveness, and enlarge energy reserves, while avoiding greenhouse gas emissions.

In Africa, a growing number of communities are turning to agroforestry, where trees are planted to delineate plots of land while further fixing nitrogen in the soil. The trees also sequester carbon, prevent soil erosion, supply firewood and animal fodder, and provide income. Organic farming can also reduce net greenhouse gas emissions while improving soil fertility through the addition of organic matter. The damage and diseases caused by insects can virtually be eliminated through the technique of "growing in corridors", which also avoids the costs of fertilisers and pesticides.

Synergies can be captured through institutional changes and stakeholder involvement.

In many countries, each environmental issue is dealt with by a different government agency. This can sometimes lead to duplication, poor information flow, inefficient resource allocation, and a general lack of coordination. Improving the links amongst national agencies and institutions can greatly strengthen the sustainable development agenda. Even greater synergies could be achieved if agencies with global and local agendas do business together.

Next steps

The IPCC's Third Assessment Report has reconfirmed that the threat of climate change is real and that there is enough evidence to warrant immediate action. It is time now to act on the basis of key decisions – decisions about how to adapt to expected impacts, how to limit and reduce greenhouse gas emissions, which priority actions to start with, and how to ensure their effectiveness and minimize their costs.

Fortunately, opportunities abound for reducing net emissions. They all involve either reducing human-induced emissions or capturing carbon dioxide from the atmosphere and sequestering it. They include investments in low-emissions technologies, institutional and regulatory changes that discourage emissions, and a wide range of technical practices and social changes. The costs of minimizing climate change can be kept relatively low by timing emissions cuts to coincide with new investments in energy production, energy use and infrastructure. There are many barriers to action, but policymakers can now accelerate their efforts to overcome them. The active participation of civil society is also vital.

Much of the debate about climate change revolves around the broader issues of development and the unequal distribution of wealth amongst the world's nations. By implementing climate policies in the context of sustainable development, and taking climate change into account in all aspects of national policy-making, governments can minimize climate change while meeting other social goals.

Although great advances have been made in understanding climate change and mitigation opportunities, research on resolving the remaining uncertainties must continue at full speed. There is a growing consensus on the availability of low-emissions technologies, and more research is needed into the barriers impeding their up-take, policies and measures for overcoming them, and their costs and benefits. However, while such studies promise to strengthen mitigation efforts over the longer term, the IPCC findings demonstrate the importance of starting to reduce emissions now.

Glossary of terms

Adaptation	Adjusting natural or human systems to cope with actual or expected climate change and its impacts.
Alternative energy	Energy derived from non-fossil fuel sources.
Anthropogenic emissions	Greenhouse gas emissions associated with human activities such as burning fossil fuels or cutting down trees.
Ancillary effects	Side effects of policies to reduce net greenhouse gas emissions, such as reductions in air pollutants associated with fossil fuels or socio-economic impacts on employment or agricultural efficiency.
Annex B countries/Parties	Developed countries included in Annex B of the Kyoto Protocol, which assigns quantitative emissions targets for the period 2008-2012.
Barrier	Any obstacle to the diffusion of cost-effective mitigation technologies or practices, whether institutional, social, economic, political, cultural or technological.
Baseline	The greenhouse gas emissions level that would occur in the absence of climate change interventions; used as a basis for analysing the effectiveness of mitigation policies.
Biofuel	Fuel produced from dry organic matter or combustible oils from plants, such as alcohol from fermented sugar, black liquor from the paper manufacturing process, wood, and soybean oil.
Biological options	There are three: conserving an existing carbon pool, and thereby preventing emissions into the atmosphere; sequestrating more CO_2 from the atmosphere by increasing the size of existing carbon pools; and substituting biological products for fossil fuels or for energy-intensive products, thereby reducing CO_2 emissions.
Biomass	The total mass of living organisms in a given area or volume; biomass can be used as a sustainable source of fuel with low or zero net emissions.
Emissions tax	A levy imposed by a government on each unit of CO_2 equivalent emissions from a source subject to the tax; can be imposed as a carbon tax to reduce carbon dioxide emissions from fossil fuels.

Emissions trading — A market-based approach to achieving environmental objectives that allows countries or companies that reduce greenhouse gas emissions below their target to sell their excess emissions credits or allowances to those that find it more difficult or expensive to meet their own targets.

Fossil fuels — Carbon-based fuels from fossil carbon deposits, including coal, oil, and natural gas.

Leakage — Occurs when emissions reductions in developed countries are partly offset by increases above baseline levels in developing countries, due to relocation of energy-intensive production, increased consumption of fossil fuels when decreased developed country demand lowers international oil prices, or changes in incomes and thus in energy demand because of better terms of trade, or when sink activities such as tree planting on one parcel of land encourage emitting activities elsewhere.

Mitigation — Action to reduce sources or enhance sinks of greenhouse gases.

No regrets policy — Policies that would generate net social benefits whether or not there is climate change; for example, the value of reduced energy costs or local pollution may exceed the costs of cutting the associated emissions.

Policies and measures — Action by government to promote emissions reductions by businesses, individuals, and other groupings; measures include technologies, processes, and practices; policies include carbon or other energy taxes and standardized fuel-efficiency standards for automobiles.

Renewables — Energy sources that, within a timeframe that is brief relative to the earth's natural cycles, are sustainable; examples are non-carbon technologies such as solar energy, hydropower, and wind, as well as carbon-neutral technologies such as biomass.

Sequestration — The process of removing and storing carbon dioxide from the atmosphere through, for example, land-use change, afforestation, reforestation, or enhancements of carbon in agricultural soils.

Spill-over effect — The economic effects of domestic or sectoral mitigation measures on other countries or sectors, which can be positive or negative and include effects on trade, carbon leakage, and the transfer and diffusion of environmentally sound technologies.

Stakeholders	People or entities with interests that would be affected by a particular action or policy.
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Subsidy	A direct payment from the government to an entity, or a tax reduction to that entity, for implementing a practice the government wishes to encourage; greenhouse gas emissions can be discouraged by reducing fossil-fuel subsidies or granting subsidies for insulating buildings or planting trees.
Technology transfer	An exchange of knowledge, money, or goods that promotes the spread of technologies for adapting to or mitigating climate change; the term generally refers to the diffusion of technologies and technological co-operation across and within countries.
Voluntary agreement	An agreement between government and business, or a unilateral private-sector commitment that is acknowledged by the government, aimed at achieving environmental objectives or improving environmental performance.
Voluntary measures	Measures to reduce greenhouse gas emissions that are adopted by firms or other actors in the absence of government mandates; they can involve making climate-friendly products or processes more readily available or encouraging consumers to incorporate environmental values in their market choices.

Information Unit for Conventions
United Nations Environment Programme
CH-1219 Geneva, Switzerland
Tel: +41 (22) 917 82 44 / 917 81 96
Fax: + 41 (22) 797 34 64
Web: www.unep.ch/conventions