Title:	Introduction	
Chapter:	Chapter 1	
(Sub)Section		
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Version:	SOD-1	
File name:	CH1_SOD-V_2 180706 Th.doc	
Date:	20/07/2006 16:10	Time-zone: CET

Chapter 1 Introduction

EXECUTIVE SUMMARY

The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner (Article 2).

This Chapter places Article 2 of the Convention in the context of the main options and conditions under which the stabilization objective has to be implemented, reflects on past and future greenhouse gas (GHG) emission trends, highlights the institutional mechanisms in place for the implementation of climate change and sustainable development objectives, summarizes changes from previous assessments and provides a brief roadmap for the "Climate Change 2007: Mitigation of Climate Change" assessment.

Defining what is dangerous interference with the climate system, and hence what are limits to be set for policy purposes is a complex task and can only partially be informed by science, as it inherently involves normative judgments. Our understanding of climate change, its impacts, vulnerability and adaptation derived from assessments of the physical science basis is that, in general, the level of climate change and attendant risks and damages increases with higher greenhouse gas concentrations, sometimes in a non linear way. Decisions made in relation to Article 2 would determine the level of climate change that is set as the goal for policy and have fundamental implications for emission reduction pathways as well as the scale of adaptation required. If warming of $2^{o}C$ above pre-industrial were deemed to be a limit on global warming, as for example set by the European Union, global emissions would need to peak within the first few decades of the 21st century and reduced to at least 70% below 2000 levels by 2100.

At present annual emissions of most GHGs are rising, especially for carbon dioxide (CO_2). Current GHG emission trends - 2.4 percent annual growth rate over the last 30 years – are projected to continue. Global energy demand and associated supply patterns based on fossil fuels – the main drivers of GHG emissions -are projected to continue to grow. As a consequence atmospheric GHG concentrations have increased annually sine the late 1950s by some 0.4 percent reaching 380 ppm in 2004. Without major emissions reductions substantially beyond the Kyoto targets, stabilization is unlikely to occur at concentration levels that would prevent dangerous anthropogenic interference with the climate system. In the context of climate change mitigation, regional differentiation is important – economic development needs, resource endowments and mitigative and adaptive capacities — are too different across regions for a one-size fits all approach.

Despite numerous mitigation measures already underway by many Parties to the UNFCCC and the entry into force of the Kyoto Protocol in February 2005 (all of which are steps towards the implementation of Article 2), these are inadequate for reversing overall GHG emission trends and achieving stabilization of atmospheric GHG concentrations. The impacts of population and economic development continue to eclipse the improvement in energy intensities and decarbonisation. The challenges confronting a reversal of emission trends are numerous including, but not limited to, compliance of emission mitigation measures with Art. 2 conditions of unhindered sustainable economic development, equity and ethics considerations, i.e., common but differentiated responsibilities and respective capabilities (Article 3), the inherent inertia of long-lived infrastructures or mitigation versus adaptation while considering the risks of abrupt or catastrophic change, and potential climate irreversibility.

Climate change responses are part and parcel of sustainable development and the two can be mutually reinforcing. Mitigation can conserve natural capital and prevent damages to human systems and, thereby, contribute socio-economic development. In turn sustainable development paths can reduce GHG emissions, contributing to the mitigation task and reducing vulnerability to climate change. Projected climate changes can exacerbate poverty and hence undermine sustainable development especially in least-developed countries, which are the most dependent on natural capital. Hence global mitigation efforts can enhance sustainable development prospects in part by reducing the risk of adverse impacts of climate change. Therefore, the main framing issue of this report is mainstreaming climate change mitigation as an integral part of sustainable development.

The Chapter closes with a brief synopsis of the changes from previous assessments and a description of the structure of the report. Although the structure of this Report (AR IV) resembles the macro-outline of the Third Assessment Report (TAR), there are distinct differences between them. The AR IV assigns greater weight to (a) a more detailed resolution of sectoral mitigation options and costs, (b) regional differentiation, (c) emphasizing previous and new cross-cutting issues: risks and uncertainties, decision and policy making, costs and potentials, and the relationships between mitigation, adaptation and sustainable development, air pollution and climate, regional aspects and the issues related to the implementation of UNFCCC Article 2, and (d) the integration of all these aspects.

1.1 Introduction

The assessment "Climate Change 2007: Mitigation of Climate Change" is of particular interest to policy makers seeking authoritative, timely information on cost-effective measures to control greenhouse gas (GHG) emissions. A thorough understanding of future GHG emission ranges, available mitigation options, mitigation potentials and associated costs is especially important for the negotiations on post-Kyoto emission reductions. Given WGI's findings of an upward change in climate sensitivity and increased risk of large scale, non-linear changes, larger emission reductions than those that emerged from the TAR (IPCC, 2001), will likely be required in order to meet the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC).

This Chapter places Article 2 of the Convention in the context of the main options and conditions under which the stabilization objective has to be implemented, reflects on past and future greenhouse gas (GHG) emission trends, highlights the institutional mechanisms in place for the implementation of climate change and sustainable development objectives, summarizes changes from previous assessments and provides a brief roadmap for the "Climate Change 2007: Mitigation of Climate Change" assessment.

1.2 Ultimate Objective of the UNFCCC

1.2.1 Article 2 of the convention

Article 2 of the UNFCCC specifies the ultimate objective of the Convention and states:

"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (UN, 1992).

The criterion that relates to enabling economic development to proceed in a sustainable manner has two sides. Projected anthropogenic climate change appears likely to adversely affect sustainable development, with adverse effects tending to increase with higher greenhouse gas concentrations (WGII AR4, Chapter 19). On the other side very costly mitigation measures could have adverse effects on economic development. This tension is what gives rise to the debate over the right scale and balance between climate policy (mitigation and adaptation) and economic growth.

The assessment of adaptation potentials in each of the areas mentioned in Art. 2 is likely to be important for a determination of what level of climate change would result in ecosystems, food production or economic development being threatened to a level sufficient to be defined as dangerous. Vulnerabilities to anthropogenic climate change are strongly regionally differentiated, with often those in the weakest position economically and politically being most susceptible to damages (Barnett and Adger, 2003) and WGII, Chapter 19, Table 19.1.

Limits to climate change consistent with Art. 2 can be defined with respect to different criteria such as concentration stabilization at a certain level, global mean temperature or sea level rise, according to which prevention of dangerous interference with the climate system can be defined. Whichever criterion is chosen its implementation would require the development of consistent emission pathways and levels of mitigation (Meinshausen et al, 2005).

1.2.2 What is dangerous interference with the climate system?

Defining what is dangerous interference with the climate system is a complex task and can only par tially be informed by science, as it inherently involves normative judgements (Oppenheimer, 2005). Definitions of danger are recognised has having "external" and "internal" dimension: the former depend on expert-determined physical vulnerability, such as disintegration of ice sheets (Oppenheimer and Alley, 2005) or risks of large scale disruptions in the earth system (Friedlingstein et al, 2003; Archer and Buffett, 2005), while the latter focuses on social, cultural and institutional contexts, and social psychology methodologies (Dessai et al, 2004). An interpretation of Art. 2 is likely to rely on political and/or legal judgements that synthesize the two perspectives (Tol and Verheyen, 2004) so as to arrive at politically defined agreements as to what may constitute unacceptable impacts on food production, ecosystems or sustainable economic development.

Over the past two decades several expert groups have sought to define levels of climate change that could be tolerable or intolerable, or characterized by different levels of risk. In the late 1980s, the WMO/ICSU/UNEP Advisory Group on Greenhouse Gases (AGGG) identified two main temperature indicators or thresholds with different levels of risk (Rijsberman and Swart, 1990). Based on the available knowledge at the time it was argued that an increase of greater than 1.0°C above pre-industrial levels "may elicit rapid, unpredictable and non-linear responses that could lead to extensive ecosystem damage". A 2ºC increase was determined to be "an upper limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly". This early work also identified rate of change as being of importance to determining level of risk, which has also been qualitatively confirmed since (Epstein and McCarthy, 2004; Leemans and Eickhout, 2004). Research since that time has tended to confirm the potential for rapid non linear responses for many different ecosystems (Burkett et al, 2005), although the degree of climate change that can bring about such responses varies by system (see Chapter 4 and WGII, Chapter 19). The question remains as to the scale and significance of such ecological risks in relation to the different elements of Art. 2. Large scale risks to ecosystems such as coral reefs also imply risks to hundreds of millions of people dependent on them (Hoegh-Guldberg, 2005).

The TAR identified five broad reasons for concern relevant to Art. 2: Risks to unique and threatened systems, risks from extreme climatic events, regional distribution of impacts, aggregate impacts and risks from large scale discontinuities. Subsequently Leemans and Eickhout (2004) have argued that a sixth ground for concern exists, i.e., regional and global impacts on ecosystems. O'Neill and Oppenheimer (2002) use a set of criteria related to ecosystems, risk of ice sheet collapse and abrupt changes in ocean circulation that could be defined as dangerous. Mastrandrea and Schneider (2004) assessed in a probabilistic manner the implications of different interpretations of dangerous anthropogenic interference in relation to the above concerns and found that climate policy can substantially reduce the risk of crossing thresholds deemed dangerous. The level of acceptable risk in each case is a matter of policy choice and normative judgement (Oppenheimer, 2005). For example the probability of a shutdown in the thermohaline circulation is currently unknown in a quantitative sense, however if it did happen it would have global consequences (Vellinga and Wood, 2002; Higgins and Vellinga, 2004; Higgins and Schneider, 2005; Levermann et al, 2005). Taking into account uncertainties reducing the risk of this to "low" levels would require early mitigation (Rahmstorf and Zickfeld, 2005).

Whilst the works cited above are principally scientific (expert-led) assessments, there are also several examples of elected officials seeking to define acceptable levels of climate change based on interpretations of scientific findings. In 1996, based on a consideration of the Second Assessment Report (SAR) of the IPCC (IPCC, 1996), the European Union's Council of Environment Ministers (Environment Council) agreed that global temperatures should not be allowed to exceed 2°C above pre-industrial levels (CEU, 1996). The EU Environment Council reconfirmed this view in 2005 (CEU, 2005b) and this also was adopted by the 25 Heads of Government of the European Union (CEU, 2005a). To date, the EU is the only region with such a quantified limit.

Each of these views has its strengths and weaknesses. The AGGG (Rijsberman and Swart, 1990) and O'Neill and Oppenheimer (2002) views have the virtue that they are more or less transparent expert judgements based on the presented analyses. The EU Council has the virtue of a high level political judgement by elected Ministers and Heads of Government with supporting analyses of scientific findings prepared by officials.

1.2.3 Issues related to the implementation of Article 2

There are a core set of issues surrounding the implementation of Article 2 upon whose resolution hinge policy related decision making in relation to the overall level of climate change to be prevented, the scale and rate of emission reductions and the level and character of adaptation responses. These issues include the linkages between sustainable development and climate change, equity, adaptation and mitigation and risk management issues relating to inertia, irreversibility, the risk of abrupt or catastrophic changes and uncertainty. In this section we lead into these issues, most of which are further discussed in Chapters 2, 3 and 11.

Decisions made in relation to Article 2 would determine the level of climate change that is set as the goal for policy and have fundamental implications for emission reduction pathways as well as the scale of adaptation required. The emission pathways which correspond to different CO_2 stabilization levels and consequential global mean warming are reviewed in Chapter 3 (see Tables 3.3-4 and 3.5-2). An indication of the different scales of mitigation action can be seen by considering two hypothetical limits in warming: If warming of 2°C above pre-industrial were deemed to be a limit on global warming, global emissions would need to be reduced to at least 70% below 2000 levels by 2100. On the other hand if a higher level of warming such as 4°C were deemed to be a limit, then emissions may not have to peak until well after mid century and could still be well above 2000 levels in 2100.

1.2.3.1 Sustainable Development

One of the important contexts in relation to the implementation of Art. 2 is sustainable development, which is recognized as having environmental, economic and social dimensions (see Chapter 2.2). Climate change responses (including mitigation) are part and parcel of sustainable development and the two can be mutually reinforcing (Davidson et al, 2003). Mitigation can conserve or enhance natural capital (ecosystems, environment as sources and sinks for economic activities) and prevent or avoid damages to human systems and, thereby, contribute to the overall productivity of capital needed for socio-economic development including mitigative and adaptive capacity. In turn sustainable development paths can reduce vulnerability to climate change and reduce GHG emissions, contributing to the mitigation task. Projected climate changes can exacerbate poverty and hence undermine sustainable development (see e.g. WGII, Chapters 6, 9.7 and 20.8.3), especially in least-developed countries, which are the most dependent on natural capital (see Chapter 2). Hence global mitigation efforts can enhance sustainable development prospects in part by reducing the risk of adverse impacts of climate change.

1.2.3.2 Adaptation and Mitigation

Adaptation and mitigation can be complementary, substitutable or independent of each other (see WGII, Chapter 18). If complementary, adaptation reduces the costs of impacts and thus reduces the benefits of mitigation. Although adaptation and mitigation may be substitutable, they are never perfect substitutes for each other since mitigation will always be required to avoid "dangerous" climate change. Irrespective of the scale of mitigation measures in the next ten to twenty years, adaptation measures will be required due to the inertia in the climate system. Both adaptation and mitigation depend on capital assets, including social capital, and affect capital vulnerability and GHG emissions (see Chapter 2.6.2*)*. Through this mutual dependence, both are tied to sustainable development (see Chapters 2.6.3, 11.8, 12.2 and 12.3).

In terms of the mitigation required to meet the Article 2 objective, stabilization of greenhouse gas concentrations and in particular of the main greenhouse gas, CO2, requires substantial emission reductions, well beyond those built into existing agreements such as the Kyoto Protocol. The timing and rate of these reductions depends on the level of the climate goal chosen (see Chapter 3.3.5.1).

1.2.3.3 Inertia

Decisions in relation to Art 2 and on mitigation action need to take account of inertia in both the climate and socioeconomic systems (WGI, Chapter 10 and Chapter 2.3.4). Mitigation actions aimed at specific climate goals would need to take account of the response times of the atmosphere and oceans. A large part of the atmospheric response to radiative forcing changes occurs on decadal timescales but a substantial component is linked to the century time scales of the oceanic response to the same forcing changes (Senior and Mitchell, 2000; Hooss et al, 2001) (WGI, Chapter 10). Once GHG concentrations are stabilized global mean temperature would very likely stabilize within a few decades, though a further slight increase may still occur over several centuries (Hare and Meinshausen, 2005; Meehl et al, 2005) (WGI, Chapter 10). Sea level rise would however continue for many centuries after GHG stabilization due to ongoing heat uptake by oceans and due to the long time scale of ice sheet response to warming (Gregory et al, 2004) (WGI, Chapter 10). There is thus a time lag between the time when mitigation is applied and the achievement of climate goals. The time scales for mitigation are linked to technological, social, economic, demographic and political factors. Inertia is characteristic of the energy system with its long-life infrastructures and this inertia is highly relevant to how fast greenhouse gas concentrations can be stabilized (Chapter 11.6.2 and (Janssen and De Vries, 2000; Unruh and Carrillo-Hermosilla, 2006). Adaptation measures similarly exhibit a range of time scales and there can be substantial lead times required for measures to be implemented and to take effect, particularly when it involves infrastructure (WGII, Chapter 17).

Due to inertia in both the climate and socioeconomic systems benefits from mitigation actions initiated now would lead to significant avoided climate change several decades later. Ultimately mitigation options have a greater potential to avoid climate change damages than the adaptation options presently foreseeable (Jones, 2004). Inertia in the system means that mitigation actions need to start in the short term in order to have medium and longer term benefits and to avoid lock in of carbon intensive technologies (Unruh and Carrillo-Hermosilla, 2006; Chapter 11.6.2).

1.2.3.4 Irreversibility

Irreversibility is an important aspect of the climate change issue with implications for mitigation and adaptation responses. The climate system's response to anthropogenic forcing is likely to be irreversible over human timescales (Scheffer et al, 2001) and damages are likely to be irreversible (Leemans and Eickhout, 2004; Thomas et al, 2004; Thuiller et al, 2005; Thuiller et al, 2006). Mitigation and adaptation will often require investment involving sunk (irreversible) costs in new technologies and practices (Section 2.3.2, Chapter 11.6.2, WGII, Chapter 17). Decisions makers will need to take into account these environmental, socioeconomic and technological irreversibilities in deciding on the timing and scale of mitigation action.

1.2.3.5 Risk of abrupt or catastrophic changes

Another important issue is the risk or abrupt or even catastrophic change in the climate system. Key vulnerabilities (WGII, Chapter 19.1.2.1) with potentially severe impacts that cannot be ruled out include: the possibility of abrupt climate changes, increases in extreme events, decay or disintegration of the ice sheets with multi-meter sea level rise, a shutdown of the North Atlantic thermohaline circulation (Rahmstorf and Zickfeld, 2005) with far reaching, adverse ecological and agricultural consequences (Vellinga and Wood, 2002; Higgins and Vellinga, 2004; Higgins and Schneider, 2005); increases in the frequency of droughts (Salinger, 2005) or a higher intensity of tropical cyclones (Knutson and Tuleya, 2004; Emanuel, 2005; Trenberth, 2005) and the risk of positive feedbacks from warming may cause the release of carbon or methane from the terrestrial biosphere and soils (Shindell et al, 2004; Jones et al, 2005) and oceans (Archer et al, 2004; Archer and Buffett, 2005) which would add to the mitigation required.

1.2.3.6 Uncertainty

Uncertainty in knowledge is an important aspect in the implementation of Art. 2 whether it is, assessing future GHG emissions or the severity of climate change impacts and regional changes (Giorgi, 2005; Giorgi and Bi, 2005), evaluating these impacts over many generations, estimating mitigation costs, or evaluating the level of mitigation action needed to reduce risk (Baranzini et al, 2003). Notwithstanding these uncertainties, mitigation will reduce the risk of both global mean and regional changes and the risk of abrupt changes in the climate system.

Under uncertainty (see Chapters 2.3. and 2.4), decision making on the implementation of Art.2 needs to incorporates risk management principles. A "precautionary and anticipatory risk management" approach should incorporate adaptation and preventive mitigation (Obersteiner *et al*, 2001a, 2001b) based on the costs and benefits of avoided climate change damage (see Chapter 3.5).

1.2.3.7 Public Good

One of the important features of the prevention regime against dangerous interference with the climate system is its global public good nature. A regime is a set of shared principles, norms, rules, rights, ways of defining problems and decision-making procedures, all embedded in institutions and infrastructures essentially operating best under cooperation (Parson and Ward, 1998).

Climate tends to be overused (excessive GHG concentrations) because of its natural availability as a resource whose access is open to all free of charge. In contrast, dangerous climate system prevention tends to be underprovided. The benefits of avoided climate change are spatially indivisible, freely available to all (non-excludability), irrespective whether one is contributing the regime costs or not. Regime benefits by one individual (nation) do not diminish their availability to others (non-rivalry). Therefore one is unable to enforce binding agreements about them[1] (Kaul *et al*, 1999; 2003) and may result in "free riding", i.e., mitigation costs are borne by some individuals (nations) while others succeed in evading them but still enjoy mitigation benefits).

The incentive to evade increases with the substitutability of individual mitigation efforts (mitigation is largely additive) and with the inequality of the distribution of net benefits. However, individual mitigation costs decrease with efficient mitigation actions undertaken by others. Because mitigation efforts are additive, the larger the number of participants, the smaller the individual cost of providing the public good, i.e., GHG stabilization.

1.2.3.8 Equity

Equity is an important guiding principle for the implementation of Art.2. Equity is an ethical construct that demands the articulation and implementation of choices about the distribution of rights to benefits and responsibilities for costs resulting from particular circumstances, say climate change, within and among communities including future generations. Climate change is subject to a very asymmetric distribution of present emissions and future impacts and vulnerabilities. Moreover, the costs of future mitigation depend upon the timing of the current mitigation efforts (Chapter 2.7) and equity can be elaborated in terms of distributing the costs of abatement or adaptation, distributing future emission rights, and ensuring institutional and procedural fairness (Chapter 13.3.4.3).

Equity exhibits preventative (avoid damage inflicted on others), retributive (sanctions), and corrective elements (e.g., 'common but differentiated responsibilities') (Ikeme, 2003 and Chapter 2.7), each of which has a place in the international response to the climate change problem (Chapter 13).

1.3 Energy, Emissions and R&D Trends – Are We On Track?

1.3.1 Last Three Decades

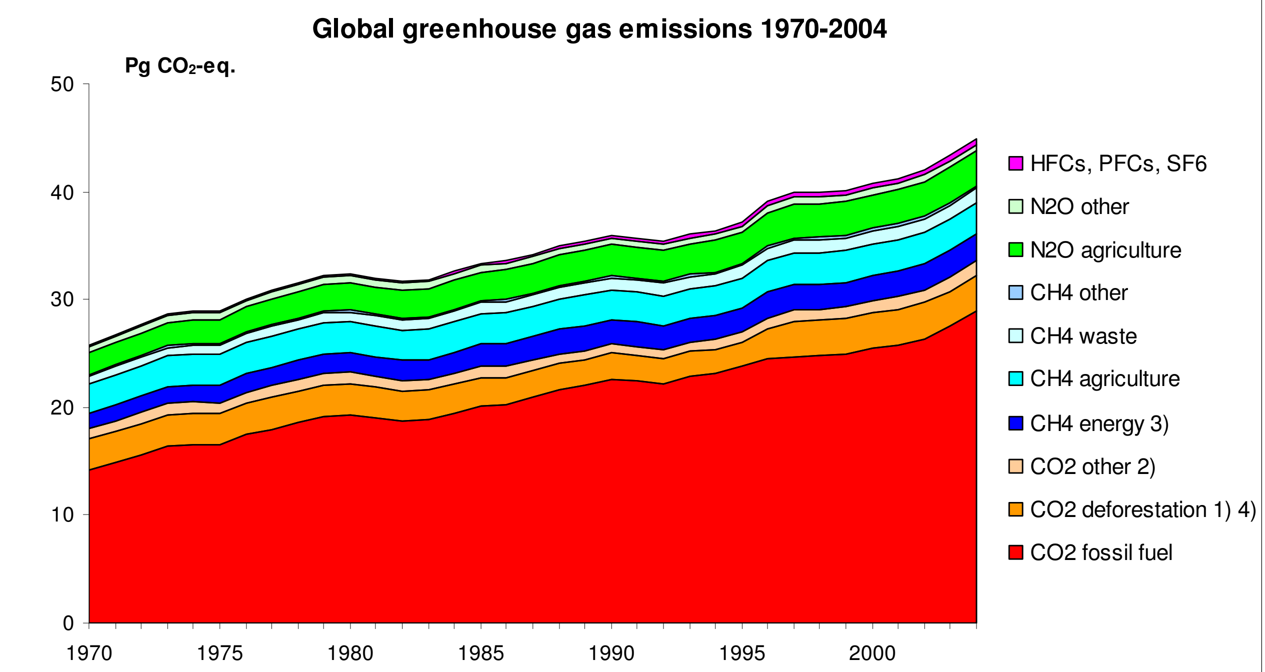
From the atmospheric point of view it is clear that the total radiative forcing of the Earth's climate due to increases in the concentrations of the long lived greenhouse gases (CO_2, methane (CH_4), and nitrous oxide (N_2O)), and the rate of observed increase in these gases over the past century, are unprecedented in at least the last 20,000 years. The predominant sources of these gases are from the combustion of fossil fuels.

A variety of sources exist for determining global and regional greenhouse gas and other climate forcing agent trends. Each source has its strengths and weaknesses and uncertainties. The EDGAR database (Olivier et al, 2005a and 2005b) contains global emission trends by broad sectors from 1970-2004. Marland et. al., (2006) contains carbon dioxide and methane emissions globally. With respect to the gases contained in both databases, they show a similar evolution in emissions. Since 1970 emissions of greenhouse gases (not including ozone depleting substances (ODS) controlled by the Montreal Protocol) have increased by approximately 75%, with CO_2 being the largest source

[1] Resulting in a prisoners' dilemma situation because of insufficient incentives to cooperate.

having grown by about 87% (Figure 1.1) and representing 75% of total anthropogenic emissions in 2004. Radiative forcing as a result of increases in atmospheric CO_2 concentrations caused by human activities since the pre-industrial era dominates that of all other radiative forcing agents. With respect to other greenhouse gases, methane emissions rose by about 40% from 1970, with an 84% increase arising from combustion and use of fossil fuels and agricultural emissions remained roughly stable due to compensating falls and increases in rice and livestock production respectively. Nitrous oxide emissions grew by 50% since 1970, mainly due to increased use of fertilizer and the growth of agriculture. Industrial process emission of N_2O fell during this period.

Use and emissions of all fluorinated gases (including the Montreal Protocol ODS) decreased substantially during 1990-2004. The emissions of one type of the fluorinated gases (HFCs) grew rapidly during this period as they replaced ODS and were estimated to make up about 1.2% of emissions on a 100 year global warming potential (GWP) basis in 2004. Current annual emissions of all fluorinated gases are estimated at 0.68 GtCeq, with HFCs at 0.11 GtCeq. Stocks are much larger and currently represent about 5.7 GtCeq. In some applications, the use of fluorinated gases increases energy efficiency, thereby reducing CO_2 emissions. Use of replacements --with often negligible GWP and comparable energy efficiency -- may have a lower climate impact than the use of fluorinated gases, in particular if considered together with energy related CO_2 emissions, assuming all gases are eventually emitted.



Data sources: 1970-2000: EDGAR 3.2, EDGAR 3.2 FT 2000; 2001-2004: IEA, USGG, AFEAS, RAND, FAO,

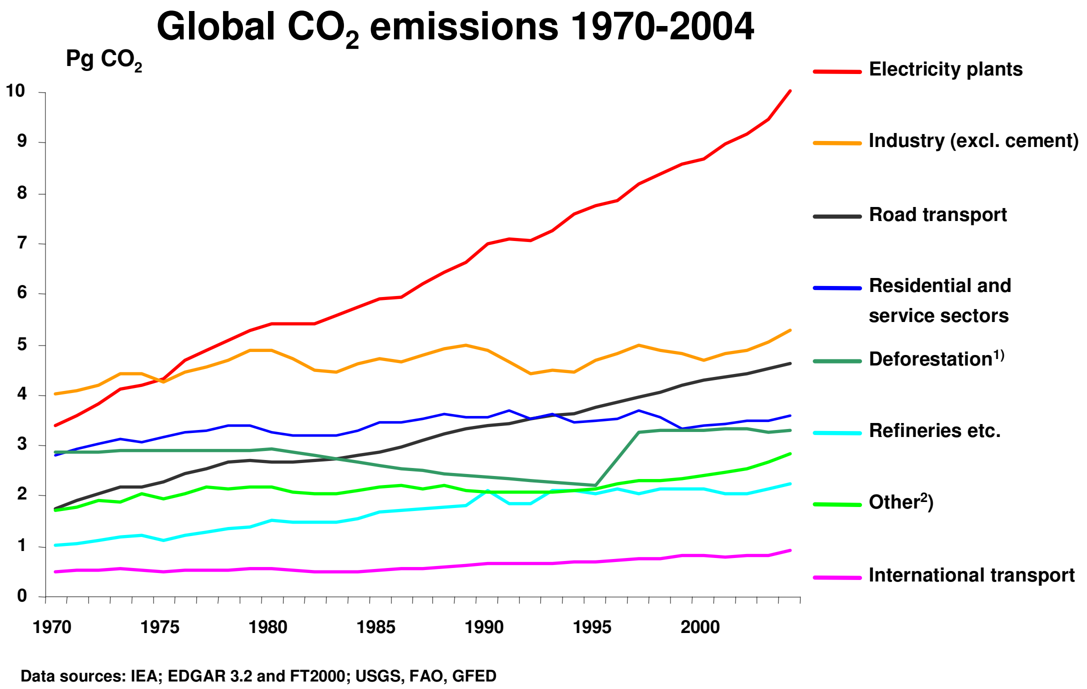
1) Including biofuel combustion at 10% (assuming 90% sustainable production).
2) Including natural gas venting/flaring
3) Including biofuels
4) For large-scale biomass burning averaged activity data for 1997-2002 were used from GFED. based on satellite data.

Note: 100 year GWPs from IPCC 1996 (SAR) were used to convert emissions to CO2-eq. (cf. UNFCCC reporting guidelines). 1 $PgCO_2eq$=1 $GtCO_2eq$.

Figure 1.1: *Global greenhouse gas trends 1970-2004*

The largest growth in CO_2 emissions has come from power generation and road transport, with industry, households and the service sector remaining at approximately the same levels for the

1970-2004 period (Figure 1.2). By 2004 CO_2 emissions from power generation represented over



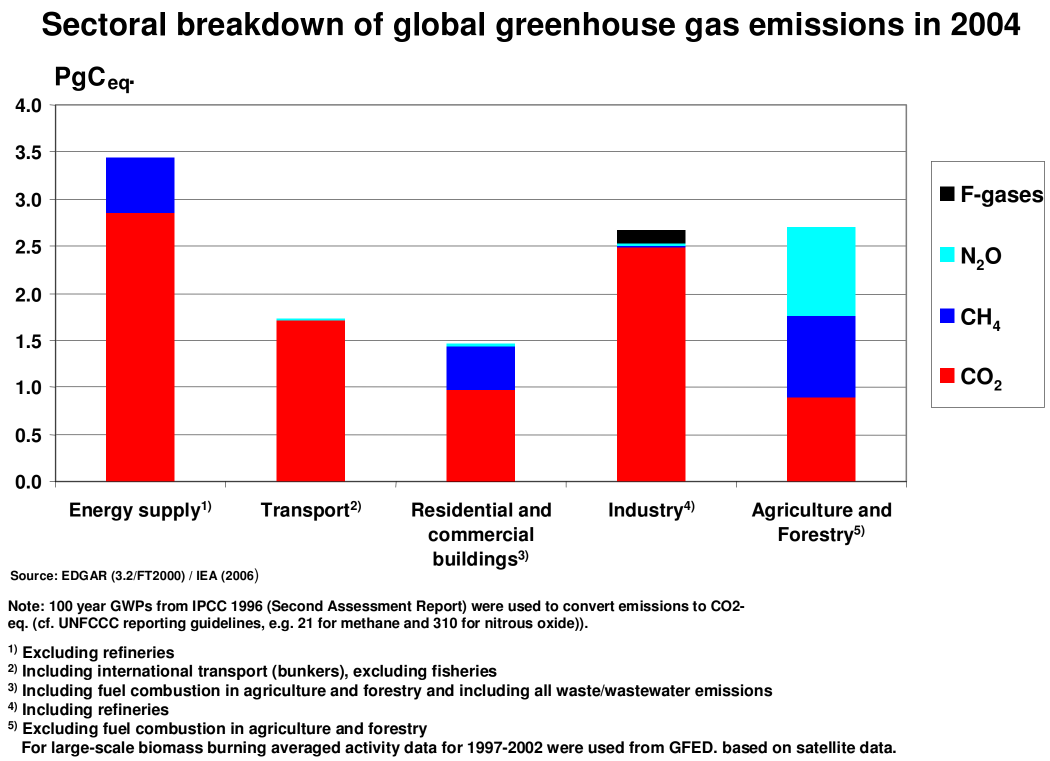
1) Including fuel wood at 10% net contribution
For large-scale biomass burning averaged activity data for 1997-2002 were used from GFED. based on satellite data
2) Other domestic surface transport, non-energetic use of fuels, cement production, and venting/flaring of gas from oil production

30% of total anthropogenic CO_2 emissions and was by far the most important source.

***Figure 1.2**: Sources of Global CO2 emissions 1970-2004*

Following the sectoral breakdown adopted in the AR4 (Chapters 4 - 10), in 2004 about 29% of GHG emissions arose from energy supply, about 22% from industry, 23% from agriculture and forestry, 14% from transport, and 12% from residential, commercial and service sectors (see Figure 1.3). These figures should be seen as indicative as some uncertainty remains, particularly with regards to CH_4 and N_20 emissions (error margin estimated to be in the order of 30% to 50%) and CO_2 emissions from agriculture (error margin up to 100%).

Since 1970 emissions from the energy supply sector have grown by over 145% while transport emissions grew by over 120% - by far the two sectors with the largest GHG emissions growth. Industry sector's emissions grew by close to 65% while the agriculture and forestry sector saw the slowest growth of 25% between 1970 and 2004.



Note: 100 year GWPs from IPCC 1996 (Second Assessment Report) were used to convert emissions to CO2-eq. (cf. UNFCCC reporting guidelines, e.g. 21 for methane and 310 for nitrous oxide)).

Note: The uncertainty in the figures is quite large for CH4, N2O and N2O (of the order of 30 to 50%) and in CO2 from Agriculture and Forestry (about 100%)

1) Excluding refineries, coke ovens etc.
2) Including international transport (bunkers), excluding fisheries
3) Including all waste/wastewater emissions
4) Including refineries, coke ovens etc.
5) Including agricultural waste burning and savannah burning
For large-scale biomass burning averaged activity data for 1997-2002 were used from GFED. based on satellite data.

Figure 1.3: GHG emission by sector (2004)

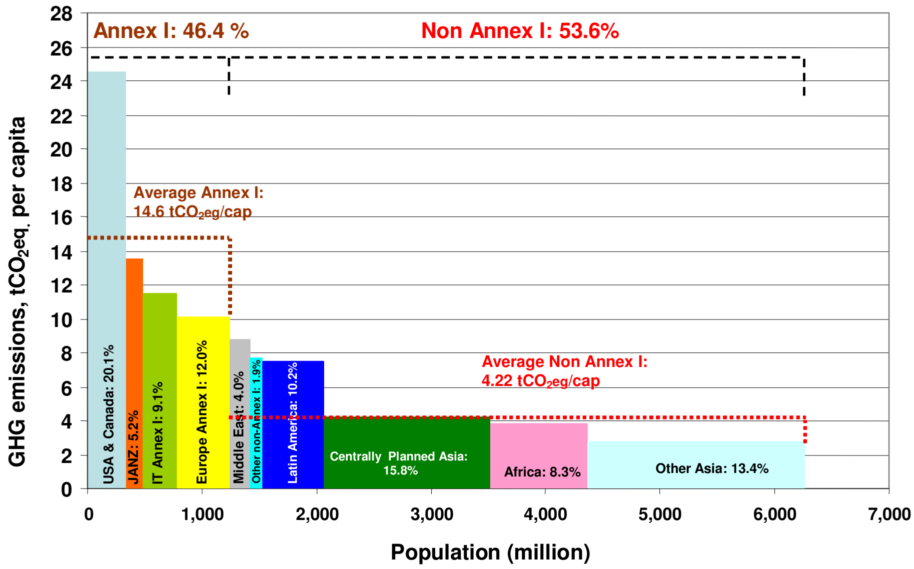
The UNFCCC reporting system for the Annex I parties provide another indication of the role of GHG emission sources. Table 1.1 gives an indication of the relative sources of emissions from the broad source categories in the UNFCCC system, reinforcing the dominant role of fossil fuel combustion and also indicating that transport related emissions are also a substantial source.

Table1.1: *Annex I emissions: Average of 1990-2003*

Source	% of emissions
Fossil fuel combustion	62.0%
Transport	20.6%
Industrial processes	5.9%
Agriculture	8.3%
Waste	3.1%
Other	0.1%

Source: Compiled from UNFCCC Greenhouse Gas Inventory Data (http://ghg.unfccc.int/index.html)
Note: Countries with incomplete data series excluded from calculation: Belarus, Lichtenstein, Lithuania, Luxembourg, Russian Federation

On a geographic basis, there are important differences between regions. North America, Asia and the Middle East have driven the rise in emissions since 1972. The former region of the Soviet Union has shown significant reductions in carbon dioxide emissions since 1990 reaching a level slightly lower than the region had in 1972. Developed countries (UNFCCC Annex 1 countries) hold a 20% share in world population but account for 46.4% of global GHG emissions. In contrast, the 80% of people living in developing countries (non-Annex 1 countries) account for 53.6% of GHG emissions (see Figure 1.4).



Note: Height of bars gives the average annual emissions of all GHGs in tCO_2 equivalent.
Width of bars gives the population.
Percentages given indicate the fraction of 2003 global emissions attributed to each region.

Figure 1.4: Distribution of regional per capita CO_2 emissions over different country groupings in 2003 (adapted from Bolin and Khesgi, 2001 using IEA (2005a) and EDGAR 3.0 database

Promotion of energy efficiency improvements and fuel switching are some of the most frequently applied policy measures which result in mitigation of GHG emissions. Although they may not necessarily be targeted at GHG emission mitigation, such policy measures do have a strong impact in lowering the emission level from where it would be otherwise.

According to an analysis of GHG mitigation activities in selected developing countries by Chandler *et al*, (2002), the substitution of gasoline-fuelled cars with ethanol fuelled-cars and conventional CHP plants with sugar-cane bagasse CHP plants in Brazil resulted in an estimated carbon emission abatement of 6.4 MtC in 2000 (compared with the actual emission of 91 MtC in 2000). According to the same study, economic and energy reforms in China curbed the use of low-grade coal resulting in avoided emissions of some 100 MtC (compared with actual emissions of 848 MtC). In India, energy policy initiatives including demand-side efficiency improvements are estimated to have reduced emission by 18 MtC (compared with the actual emission level of 290 MtC). In Mexico, the switch to natural gas, the promotion of efficiency improvements and lower deforestation, are estimated at 10 MtC of emission reductions, compared with actual emissions of 187 MtC.

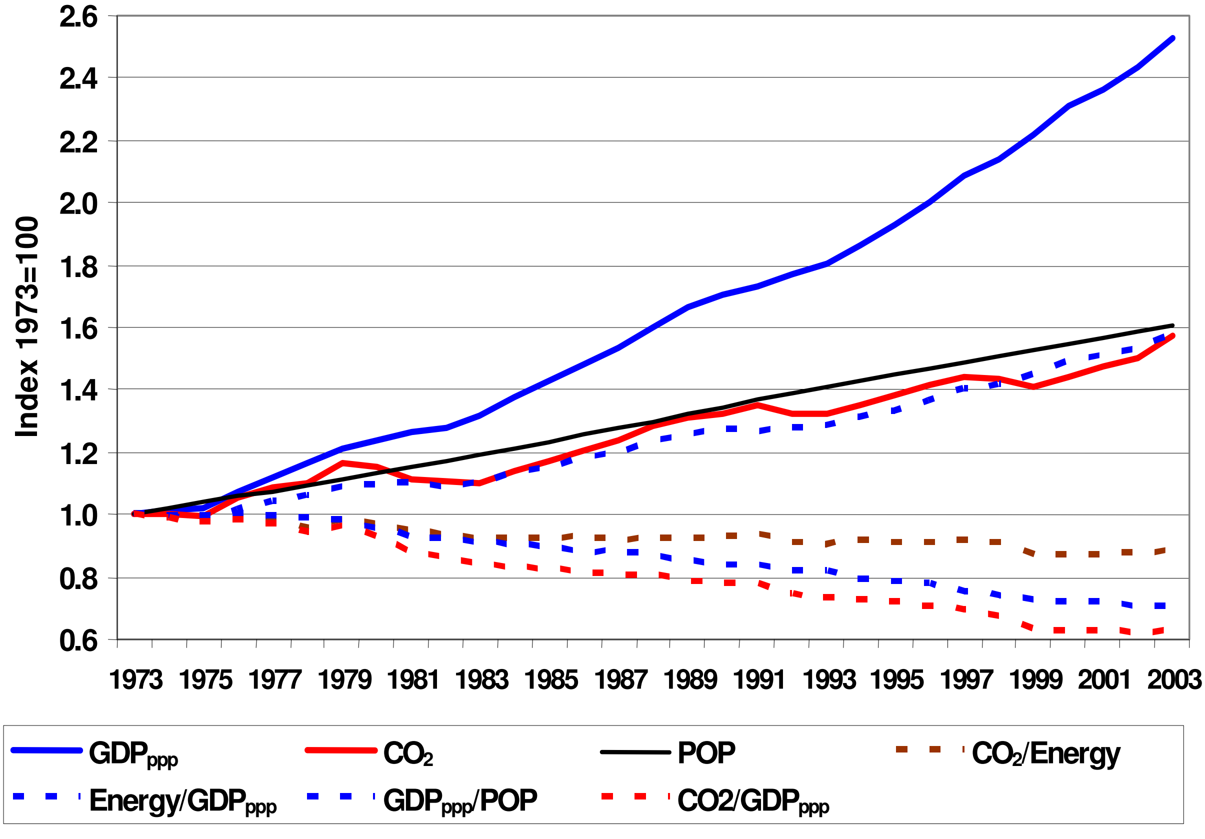
For the EU-25 countries, (2006) provides a rough estimate of the avoided CO_2 emissions from public electricity and heat generation due to efficiency improvements and fuel switching. If the efficiency and fuel mix had remained at their 1990 values, emissions in 2003 would have been some 31% above actual emissions.

1.3.1.1 Energy Supply

Global primary energy use almost doubled from 229 EJ in 1971 to 449 EJ in 2003 with an average annual growth of 2.1%/yr over this period. Fossil fuels accounted for 80% of total energy use in 2003 – slightly down from the 86% more than 30 years ago mainly due to the increase of nuclear energy. Despite substantial growth of non-traditional renewable forms of energy over the last decade, the share of renewables (including traditional biomass) in the primary energy mix has not changed compared with 1971 (see Chapter 4).

1.3.1.2 Energy Intensities

The Kaya-identity (Kaya, 1990) recognizes four aggregate driving forces of CO_2 emissions and decomposes emission growth into: a) population growth, b) gross domestic product per capita (GDP/cap), c) energy-intensity (energy per unit of GDP), and d) carbon-intensity (CO_2 emissions per unit of energy). Globally, the average growth rate of CO_2 emissions between 1973 and 2003 of 1.5% p.a. is the result of (see Figure 1.5): population growth: 1.6% p.a.; GDP/cap[2]: 1.6% p.a.; energy-intensity: -1.0% p.a.; and carbon-intensity: -0.7% p.a.



Note: GDP (PPP) of 1973 and 1974 was unavailable and is therefore estimated by using the growth rate of non-PPP GDP.

Figure 1.5: *Gross Domestic Product both in terms of absolute (GDP) and per capita (GDP/POP) measured in PPP (Purchase Power Parity), Population (POP), Energy Intensity (Energy Use per GDP), Carbon Intensity (CO_2/Energy Use), and Carbon Dioxide Emissions (from fossil fuel burning, gas flaring and cement manufacturing). Sources: World Bank, 2005; Marland et.al, 2006.*

[2] Purchasing power parity (PPP) at 2000 prices and exchange rates

As the decomposition analysis indicates (see Figure 1.6), for the last three decades GDP/capita growth and population growth were the main drivers of the increase in global emissions. Moreover, structural changes of the global energy system were mainly due to the reduced energy intensity. The role of carbon intensity in offsetting emission growth was in fact declining over the last two decades. The reduction of carbon-intensity was strongest between 1973 and 1983 caused by the two oil shocks and approached zero during the 1993-2003 decade. At the global scale, declining carbon and energy intensities could not offset population growth and income effects, and consequently carbon emissions have risen.

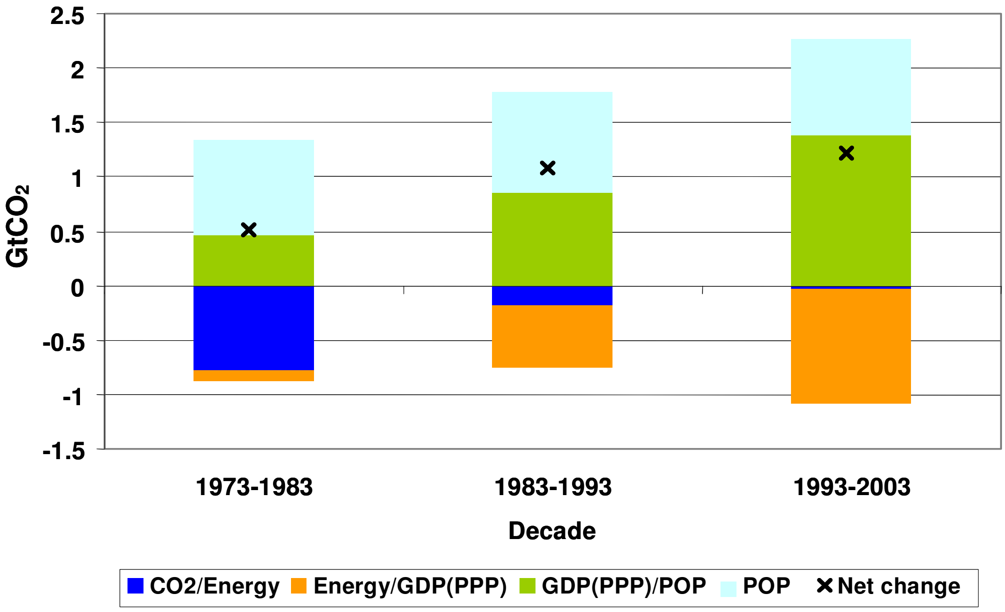
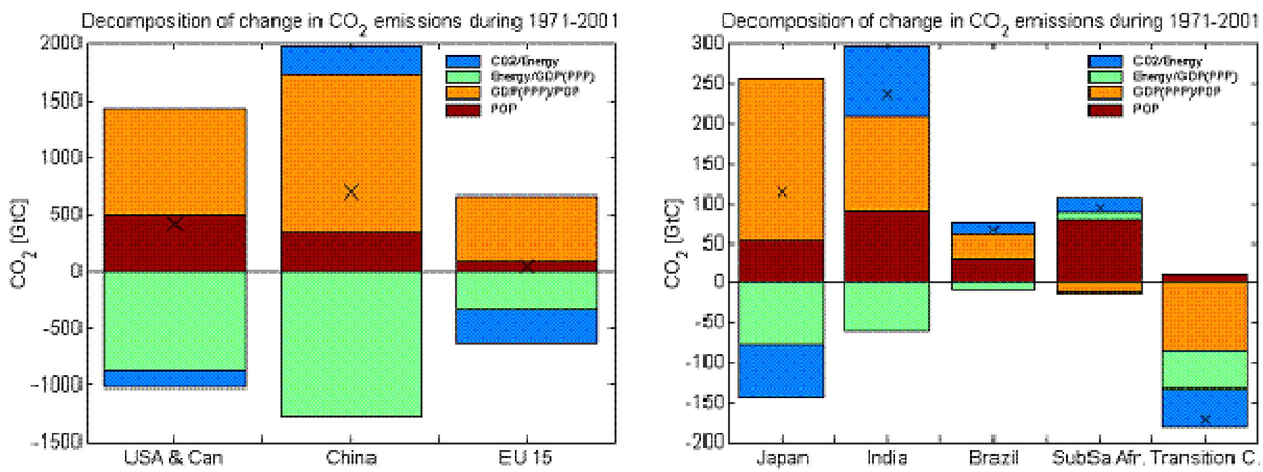


Figure 1.6: *Decomposition of CO2 emission growth at global scale, shown for three decades. Sources: World Bank, 2005; Marland et al., 2006.*



Note: for Transition Countries the time horizon is restricted to 1981-2001.

Figure 1.7*: Decomposition of absolute change in carbon dioxide emissions during 1971-2001 for the USA, Canada, China, EU (15), Japan, India, Brazil Africa and Transition Countries[3]. Sources: World Bank, 2004; WRI, 2006.*

[3] Includes Albania, Bulgaria, Estonia, Georgia, Hungary, Latvia, Romania, and Russian Federation. In some cases when data for 1981 was unavailable the value for 1980 was used.

At a regional scale, no country – except the Transition Countries (refers to 1981-2001 only) – from the club of the main emitters (North America, Western Europe, China, Brazil, Japan) has reduced its emission in absolute terms (see Figure 1.7).

Decarbonisation was highest in Western Europe, but the effect only led to a reduction in the growth rate of CO_2 emissions and not to a reduction of CO_2 in absolute terms. The declining energy-intensity in Western Europe was mainly induced by a structural change towards less energy intensive production processes (services, information technologies). The reduction of carbon-intensity was caused by fuel switching to less carbon intensive fuels, e.g., from coal to gas and oil or from coal and oil to nuclear and hydro for electricity generation. Together with Western Europe, US/Canada and Japan were the only economies that reduced carbon-intensity substantially. In North America, the decreasing energy intensity between 1980 and 1990 was partly an effect of an energy policy started after the two oil crises. Moreover, both oil shocks have accelerated the ongoing structural change towards a service and knowledge-based economy.

Despite declining energy intensities in China and India, massive coal and oil use have led to increasing carbon intensities in these countries. In India, traditional biomass is increasingly substituted by coal – a development that raised carbon-intensity. China's decline in energy intensity is, to a large extent, the result of the closure of numerous small and inefficient factories as well as of foreign direct investments in more energy efficient electricity generation. It appears that rising carbon intensities accompany the early stages of the industrialization process which is closely linked with accelerated electricity generation mainly based on fossil fuels (primarily coal). In addition, the emerging but rapidly growing transport sector is fueled by oil which further contributes to increasing carbon intensities. Stepped-up fossil fuel use, GDP/capita growth, and to a lesser extent population growth, result in the dramatic increase in carbon emissions in India and China.

The Transition Countries of Eastern Europe and the former Soviet Union have suffered declining incomes per capita as a result of the collapse of their economies. As a result total GHG emissions were greatly reduced. However, the continued low level of energy efficiency in using coal, oil and gas allowed only moderate improvements in carbon and energy intensities. Despite of its economic decline, this group of countries accounts for 12 % of global CO_2 emissions in 2004.

The challenge – an absolute reduction of global GHG emissions – is therefore quite formidable. It presupposes a reduction of energy and carbon intensities at a faster rate than income and population growth taken together. Admittedly, there are many possible combinations of the four Kaya identity components. However Art. 2 requires the prevention of dangerous interference with the climate system "within a timeframe" that ecosystems can adapt naturally, ensure food production is not threatened and that enables economic development to proceed in a sustainable manner. And the scope and legitimacy of controlling population development is subject to ongoing debate. Therefore, the remaining two, technology-oriented factors energy and carbon intensities have to bear the main burden. In addition, it is also open to debate in how far different economies at different stages of development are willing and able to reduce carbon and energy intensities to a level which is compatible with Art. 2.

1.3.1.3 Energy Security

With international oil prices fluctuating around 70 US$ per barrel (Brent Crude in the first half of 2006 - EIA, 2006) and with prices of internationally traded natural gas, coal and uranium following suit, energy supply security concerns are back on the agenda of many public and private sector institutions. Consequently, there is renewed public interest in alternatives to fossil fuels, especially to oil, resulting in new technology initiatives to promote hydrogen, nuclear power and renewables[4]. However, energy security concerns tend to first of all invigorate a higher reliance on indigenous energy supplies and resources. Regions where coal is the dominant domestic energy resource tend to use more coal, especially for electricity generation, which increases greenhouse gas emissions. In recent years, intensified coal use has been observed in Asian developing countries, North America and some European countries.

Energy security is part and parcel of sustainable development and plays a non-negligible role in mitigating climate change. Striving for enhanced energy security can impact GHG emissions in opposite ways. On the one hand, GHG emissions may be reduced by stimulating rational energy use, efficiency improvements, innovation and development of alternative energy technologies with inherent climate benefits. On the other hand, measures supporting energy security may lead to higher GHG emissions due to stepped-up use of indigenous coal or the development of lower quality and unconventional oil resources. Considering the fact that equipping or building coal fired power plants with CO_2 capture and storage (CCS) is in its infancy and CCS, at least initially, faces a considerable cost premium and alternatives to fossil fuels can not yet meet the demand for secure and affordable energy supplies, the conventional coal combustion is likely to dominate in the short to medium run.

1.3.2 Future Outlook

1.3.2.1 Energy Supply

There are a variety of projections of the energy picture for the coming decades. They differ in terms of their modeling structure and input assumptions, in particular about the evolution of policy in the coming decades. For example, the IEA's World Energy Outlook 2005 (IEA, 2004; IEA, 2005a) and the U.S. Energy Information Agency's International Energy Outlook (EIA 2005) have a set scenarios and yet organizations project continued dependence on fossil fuels (see Chapter 4 for past global energy mixes and future energy demand and supply projections). Should there be no change in energy policies, and most certainly there will be, the energy mix supplied to run the global economy of 2025-30 timeframe will essentially remain unchanged with about 80% of energy supply based on fossil fuels. In other words, the energy economy may evolve, but not radically change unless policies change.

According to the IEA and EIA projections, coal (1.5% - 2.5% p.a.), oil (1.0% - 2.0% p.a.) and natural gas (1.9% – 3.0% p.a.) all continue to grow in the period up to 2030. Among the non-fossil fuels, nuclear (0.4% - 1.0% p.a.), hydro (1.8% p.a.), biomass and waste including non-commercial biomass (1.3% p.a.) and other renewables (5.7% p.a.)[5] also continue to grow over the projection period. New renewables growth while robust starts from a relatively small base. Sectoral growth in energy demand is principally in electricity generation and transport sectors. Together their share of global energy will reach 60% by 2030.

1.3.2.2 Carbon Dioxide Emissions

Global growth in fossil fuel demand has a significant effect on energy related carbon emissions growth – better than 50% growth in the respective forecast periods of the EIA and IEA. Both project

[4] For example, International Partnership for a Hydrogen Economy and the Asian-Pacific Partnership
[5] EIA reports only an aggregate annual growth rate for all renewables between 1.5% and 3.0% p.a.

at least an annual growth rate of 1.6% in the absence of additional policies (see Figure 1.8). According to IEA projections, emissions will reach 10.4 GtC in 2030, an increase of 4.1 GtC over the 2002 level.

As the bulk of energy demand growth occurs in developing countries, the emissions growth accordingly is dominated by developing countries. They represent more than two thirds of IEA projected increase in global energy related emissions. Developing countries, which accounted for 36% of total emissions in 2002, will notably overtake OECD as the leading contributor to global emissions in the early 2020s.

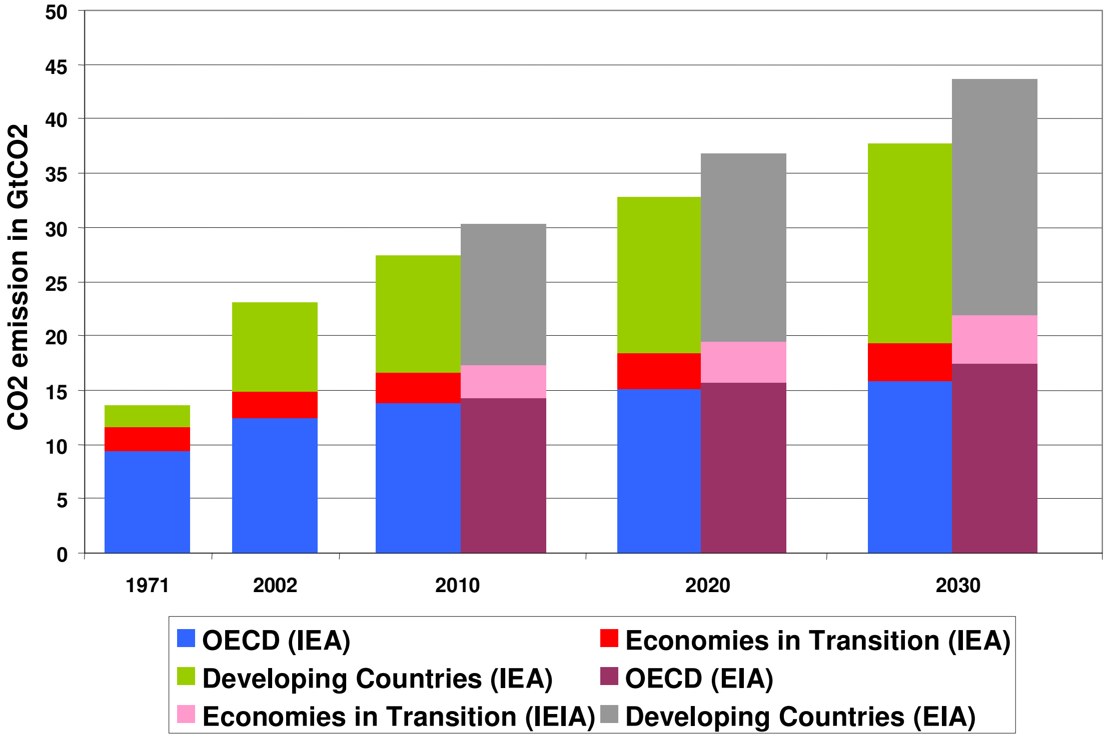


***Figure 1.8**: CO2 projections (Sources: IEA, 2004; IEA, 2005a and EIA, 2006*

The higher global growth rate of natural gas demand is reflected in CO2 emissions projections. The IEA projects the share of total energy related emissions accounted for by gas to increase from 21% in 2002 to 24% in 2030 while the share of coal and oil both drop by approximately 2%, to respectively 36% and 39% of total. At the global level, sectoral distribution of emissions is projected to remain relatively stable. Heat and power generation will continue to be the main source of energy related emissions, accounting for 44% of the total by 2030, followed by the transport sector (23%), and industry (15%).

1.3.2.3 Non-CO2 Gases

Fluorinated gases

Predicting overall environmental impacts is complicated by the fact that several major applications retain the bulk of their fluorinated gases during their respective lifecycles, resulting in the accumulation of significant stocks which need to be responsibly managed when these applications are decommissioned. Evaluating emission scenarios and their environmental impacts is therefore a complex task, involving parameters such as economic growth, technology selection, regional climatic variation, and emission factors for the operational phase and at end-of-life for the different application sectors considered. A comprehensive review of such assessments was published in an earlier IPCC study (IPCC, 2005). Chapter 3 also details results of long-term greenhouse gas emissions scenarios. It points to the work done in the context of EMF 21. According to the various baseline scenarios in this study, emissions of fluorinated gases will range between 0.44 GtC_{eq} to 0.79 GtC_{eq} (average of 0.57 GtC_{eq}) in 2050. On average, this represents close to a three fold increase from 2004 values.

Methane

Atmospheric concentrations have increased throughout most of the 20th century, but appear rather stable over the last 5-10 years. So far it is believed that this stabilization is the result of land-use changes. Agriculture and forestry developments are assessed in Chapters 8 and 9 concerning their impact on the methane sink/source balance and mitigation strategies. The same applies to waste handling (Chapter 10).

EMF 21 baseline scenarios for Methane show a range of between 1.88 GtC_{eq} and 3.82 GtC_{eq} in 2050 with an average value of 2.84 GtC_{eq}. This represents on average a 48% increase compared to 2004 data.

Nitrous oxide

Atmospheric concentrations have been continuously increasing, however, with at a small annual growth rate. Industrial sources, agriculture and forestry developments are assessed in this report concerning their impact on the nitrous oxide sink/source balance and mitigation strategies.

According to the EMF study, baseline Nitrous Oxide emissions will range between 0.52 GtC_{eq} to 1.82 GtC_{eq} (average of 1.23 $GtC_{e}q$) for 2050 - a 17% rise on average compared to 2004 levels

1.3.2.4 Total GHG Emissions

It appears from business as usual scenarios that GHG emissions will continue to rise. Even alterative scenarios that account for policies currently under discussion show global emissions rising. From an emissions perspective it appears we are not on track in meeting the objectives of Art.2.

1.3.3 Research and Development Needs and Trends

1.3.3.1 Research and Development

Technology research and development hold the key for altering the emission trends shown in the previous sections. In the absence of measures fostering the development of climate friendly technologies and/or lack of incentives for their deployment, however, it is a priori not obvious in which direction. Because of the longevity of energy infrastructures (lock-in effect) development and diffusion of technological systems may take many decades, near-term - not long term - technology investment decisions determine the direction of long-term development of the energy system (Gritsevskyi and Nakicenovic, 2002).

Generally speaking, it would be economically impossible, without technology research, development, demonstration, deployment and diffusion (RDDD&D) and Induced Technology Change (ITC), to stabilize GHG concentration at a level that would prevent DAI with the climate system. A recent international modeling comparison exercise (Edenhofer *et al*, 2006) has shown that

ITC has not only the potential to reduce mitigation costs substantially but it is also essential to stabilize concentration levels of CO_2 avoiding dangerous climate change. However, RDDD&D alone is insufficient, i.e. effective climate policies are also required (Baker *et al*, 2006) and the addition of many new technologies reduction of net emissions or stabilization of CO_2 concentration may not necessarily occur without an explicit limit on emissions (Edmonds, 2004).

There are various types of technologies including but not limited to: solar, wind, nuclear fission and fusion, geothermal, biomass, fuel cells, clean fossil technologies including carbon capture and storage, hydrogen production from non-fossil energy sources and energy efficiency improvements throughout the energy system, especially at the end use side - industry, commercial, transport and household –that can play significant roles in mitigating climate change (Nordhaus, 2002; Pacala and Socolow, 2004; Akimoto *et al*, 2005). Some of them are in their infancy and require public RDDD&D support, while others are more mature and need only market incentives for their deployment and diffusion. Some of them may also need persevering efforts for public acceptance (Tokushige *et al*, 2006) as well as the resolution of legal and liability issues.

1.3.3.2 Research and Development Expenditures

As Figure 1.9 demonstrates, the most rapid growth in energy related technology R&D was after the oil price shocks of the 1970s. There is no evidence yet of a similar response from the latest price surges although it may be premature for that response to appear in the data. It is clear, however, that a technology R&D response to the challenge of climate mitigation has not occurred. Energy technology R&D has remained roughly constant over the last 15 years as climate change has become a focus of the international policy development.

The lack of an increase in R&D funding suggests we are not on track in terms of developing the technologies that will fuel a transition to a steady state concentration level while simultaneously meeting our energy security and economic objectives.

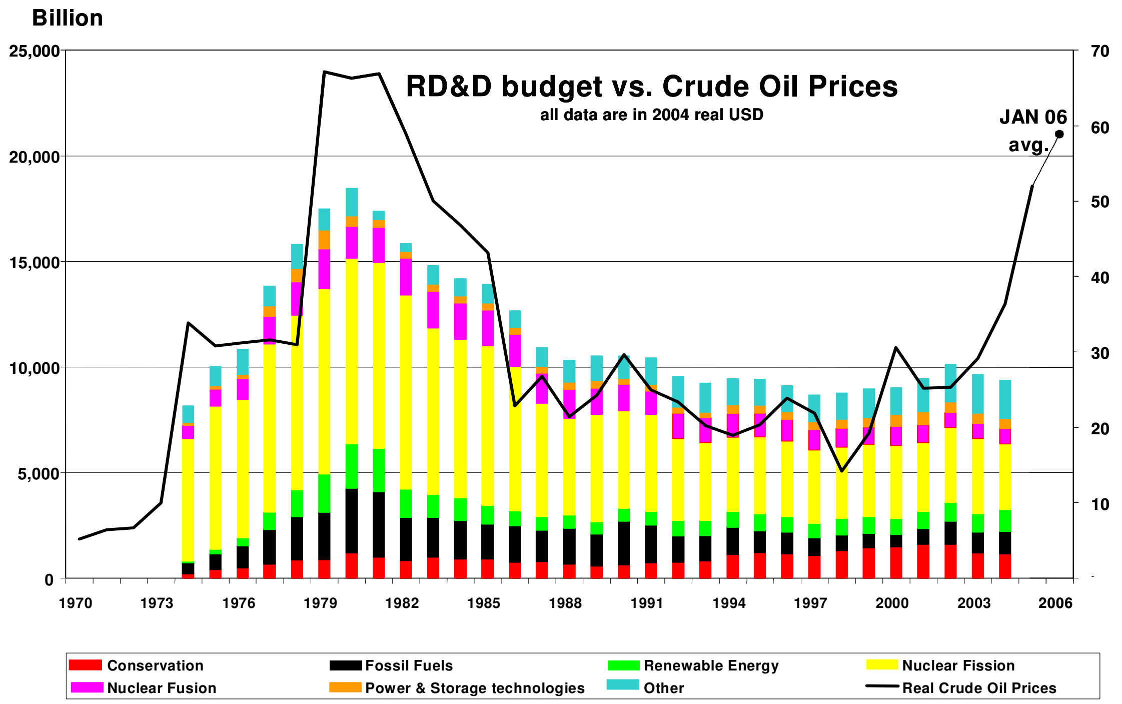


Figure 1.9: Oil prices and energy related R&D budgets. Source: IEA, 2006

International cooperation in the field of technology research and development may leverage otherwise sub critical national R&D budgets. Several international partnerships have been created in support of the development of cleaner technologies (see Section 1.4.3).

1.4 Institutional Architecture

1.4.1 UNFCCC, the Kyoto Protocol and the 2005 Montreal CoP-11/MoP-1 (CMP-1)

The United Nations Framework Convention on Climate Change was adopted in 1992 at the Rio Earth Summit with entry into force in March 1994. As of May 2004, the Convention has been ratified by 188 countries (out of the 191 UN member states)[6]. The Conference of the Parties (COP) that has met yearly since 1995 is the supreme body of the Convention (Art. 7.2). UNFCCC pursues its major objective (Section 1.2.1) on the basis of several guiding principles laid down in other articles of the Convention:

- Equity, i.e. “common but differentiated responsibilities and respective capabilities” that assign the lead of the mitigation process to developed countries (Art. 3.1), and taking the needs and special circumstances of developing countries into account, especially the ones most vulnerable to adverse effects of climate change (Art. 3.2, Art. 4.9 and 4.10).
- Precautionary principle, which says that “where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost” (Art. 3.3).
- Sustainable development promotion and taking a comprehensive policy approach by including climate change into relevant development, social, economic, and environmental policies (Art. 3.4, Art. 4.1).
- Development and transfer of relevant environmentally sound technologies by Annex II countries (mainly OECD countries listed in Annex II of the Convention) to developing countries (Art. 4.5), contribution to the full cost of “national communications” from developing countries (Art. 4.3) and assistance to Parties most vulnerable to adverse effects of climate change in meeting costs of adaptation to those adverse effects (Art. 4.4).
- Commitment by Annex I countries - with some flexibility for non-Annex II countries (Art. 4.6) - to adopt policies and measures aimed at returning, individually or jointly, their GHG emissions to earlier levels by the year 2000 (Art. 4.2)[7].

The Kyoto Protocol (KP) to the UNFCCC was adopted by consensus in 1997 at COP-3. Ratification required that 55 UNFCCC parties, representing collectively at least 55% of the 1990 Annex 1 countries’ CO_2 emissions, ratify the Protocol (Art. 25.1). It entered into force on 16 February 2005. As of February 2006, it was ratified by 161 nations (Australia, Croatia and the United States, parties to UNFCCC, did sign but did not ratify), representing 61.6 % of the 1990 CO_2 emissions. The main dispositions of KP are:

- COP meetings will also serve as the Meeting of the Parties (MOP) for the Protocol. Parties to the Convention that are not Parties to the Protocol will be able to participate in Protocol-related meetings as observers (Art. 13).
- Each Party, listed in Annex B of the Protocol, is assigned a legally binding quantified GHG emission limitation measured in CO_2 equivalents. Parties included in Annex B are expected to

[6] http://unfccc.int/files/essential_background/kyoto_protocol/application/pdf/kpstats.pdf
[7] with some flexibility for non-Annex II countries (Art. 4.6)

reduce their GHG emissions (i.e. the six gases listed in Annex A of the Protocol) by "at least 5 per cent below 1990 levels in the commitment period 2008 to 2012" (Art. 3.1) and to make demonstrable progress towards this goal by 2005 (Art. 3.2). Economies in transition may chose a base period other than 1990. (Art. 3.5, 3.7). For three GHGs the base year is 1995 (Art. 3.8).

- So-called Kyoto flexibility mechanisms allow Annex B countries to obtain credits for emissions reductions achieved outside their national borders. These mechanisms are required to be supplemental to domestic action, which is expected to be a "significant element of the effort" (Art. 6.1 (d), Art. 17, CMP 1[8]). The first one is an international emission trading system in Assigned Amount Units (AAUs). The second one is the acquisition of Emission Reduction Units (ERUs) from other Annex B Parties for Joint Implementation projects (Art. 6). The third one is the acquisition of Certified Emission Reduction Units (CERs) for projects undertaken as of year 2000 in developing (non-Annex 1) countries under the Clean Development Mechanism (CDM) in order to further sustainable development (Art. 12). The last flexibility mechanism allows the acquisition of Emission Removal Units (RMU) from carbon sinks in Annex B countries (Marrakech Accords). The 2001 COP-7 Marrakech Accords, adopted by the Montreal CMP 1 as the "Kyoto rulebook", provide for businesses, non-governmental organizations, and other entities to participate in the four mechanisms, under the authority and responsibility of governments.
- A set of procedures for emission monitoring, verification and compliance have been agreed at CMP1 under Art. 5, 7 and 8 and Art. 18. Annex I countries must keep a registry of their AAU, ERU and CER holdings. A CDM registry is maintained and an International Transactions Log (ITL) will be opened and maintained for all the above holdings by the Secretariat (CMP 1). The final status of the KP compliance procedures have been agreed to at CMP 1 and the compliance system began operating as of March 2006.
- According to Art. 3.9, the Parties to the Protocol shall initiate the consideration of post-Kyoto emission limitations at least seven years before the end of the first commitment period, i.e., by 2005. A new working group on the commitments of Annex I countries beyond 2012 was set up at CMP 1 which met in Bonn in May 2006 and agreed to negotiate binding targets for a second commitment period. A dialogue under the guidance of the COP, and taking the form of an open and non-binding exchange of views and information in support of enhanced implementation of the Convention was set up in Montreal (CMP 1) and held its first meeting in Bonn.

1.4.2 Millennium Development Goals, the Johannesburg Plan of Implementation and other International Fora

In 2000, Member States of the United-Nations adopted the Millennium Declaration (UN, 2000a) with eight Millennium Development Goals (MDG). These address developing countries' special needs, and constitute a concerted attack on poverty and the problems of illiteracy, hunger, discrimination against women, unsafe drinking water, health and a degraded environment (UNDESA, 2004). MDG # 7 requires the integration of the principles of sustainable development into country policies and programmes and reversal of the loss of environmental resources. This reinforces Art. 4.7 of UNFCCC, which states that 'economic and social development and poverty eradication are the first and overriding priorities of developing countries'.

In response to such challenges, the World Summit on Sustainable Development developed the Johannesburg Plan for Implementation (JPOI), which explicitly commits the signatories to

[8] All CMP.1 decisions can be found at http://unfccc.int/documentation/decisions/items/3597.php?dec=j&such=j&volltext=/CMP.1#beg

responsible and equitable management of the earth's resources as part of the broader effort to achieve the MDGs (UN, 2002b). Building on Agenda 21 (UNCED, 1992), the Plan privileges the first MDG, i.e. poverty reduction (Art. 6) through, among others, combating desertification and mitigating the effects of future droughts and floods (Art. 6.l), and improved access to environmentally sound energy services (Art. 8). Climate change mitigation may help reduce the future need to combat the effects of droughts and floods, facilitating the implementation of the UN Convention to Combat Desertification (see Chapter 12 for the interaction between sustainable development and climate change). The Marrakech Accords and the Monterrey Consensus on financing MDGs (UN, 2002c) are reaffirmed, as well as the need to provide technical and financial assistance and capacity building to developing countries (Art. 36, c). Art. 103.f re-affirms the precautionary principle following UNFCCC Art. 3.3 which offers yet another argument in favor of climate change mitigation.

The Commission on Sustainable Development has adopted an integrated approach to energy for sustainable development, industrial development, air pollution/atmosphere, and climate change for its 2006/2007 cycle[9]. It has emphasized at its 9th session the central role of access to environmentally sound, socially acceptable and economically viable energy, including energy efficiency and renewable energy, and of energy technology transfer for sustainable development and poverty eradication (decision 9/1)[10]. Other international fora, such as the U.N. General Assembly (A/60/L.1, 2005[11]), the G8 Dialogue on Climate Change, Clean Energy and Sustainable Development (Gleneagles, 2005), OECD (2005), WTO (Doha Development Agenda), which pursues trade liberalization, important for technology transfers (see section 1.4.3), IEA (2003), the World Bank (Sperling, 2003), and more regional ones (including regional banks) such as the EU, the Asia-Pacific Partnership on Clean Development, for transferring and deploying clean technologies and building up human and institutional capacity, etc. are important to further the agenda for sustainable development and climate change (see Chapter 13).

1.4.3 Technology cooperation and transfer

Effective and efficient mitigation of climate change depends on the rate of diffusion of new as well as existing technologies within and between countries, especially between developed and developing countries but also between developing countries themselves.

To share information and development costs internationally, there exist several examples of international cooperation for RDDD&D, such as the Carbon Sequestration Leadership Forum (CSLF), the International Partnership for Hydrogen Economy (IPHE), Generation IV International Forum (GIF), the Methane to Markets Partnership and the Renewable Energy & Energy Efficiency Partnership (REEEP). Their fields range from basic R&D and market demonstration to barrier removals for commercialization/diffusion. In addition, there are 40 "implementing agreements" facilitating international cooperation on RDDD&D under IEA (International Energy Agency) auspices, covering all the key new technologies of energy supply and end use with the exception of nuclear fission (IEA, 2005b).

Regional cooperation may be effective as well. Asia-Pacific Partnership of Clean Development and Climate (APPCDC), which was established by Australia, China, India, Japan, Korea and the

[9] http://www.un.org/esa/sustdev/csd/csd11/CSD_mulityear_prog_work.htm
[10] http://www.un.org/esa/sustdev/csd/ecn172001-19e.htm
[11] 'Integrated and coordinated implementation of and follow-up to the outcomes of the major UN conferences and summits in the economic, social and related fields'

United States in January 2006, aims to address increased energy needs and associated challenges, including air pollution, energy security, and climate change, by enhancing development, deployment, and transfer of cleaner, more efficient technologies. In September 2005, EU concluded agreements with India and China respectively, aiming to promote the development of cleaner technologies (India) and low carbon technologies (China).

There exist also bilateral sector-based cooperation agreements. One example is the Japan/China agreement on energy efficiency in the steel industry concluded in July 2005 (JISF, 2005). As energy efficiency varies greatly throughout various sectors, these sector-based initiatives for promoting technology cooperation may be an effective tool for technology transfer and mitigating GHG emissions.

1.5 Changes from previous assessments and roadmap

1.5.1 Previous Assessments

The IPCC is both an intergovernmental organization (IGO) and a scientific and technical assessment organization. The IGO meets formally to develop and approve the overall work plan, to review and 'accept' technical reports, and to 'approve' line by line summaries for policy-makers. The reports are written and reviewed by scientists and technical experts from around the world, including academics and NGO and industry representatives. Scientists are proposed by their governments and selected by the Working Group Task Force. (www.ipcc.ch/about/app-a.pdf, Jasanoff and Wynne, 1998)

The IPCC was set up in 1988 by UNEP and WMO with three working groups: to assess available scientific information on climate change (WGI), to assess environmental and socio-economic impacts (WGII), and to formulate response strategies (WGIII).

The First Assessment Report (FAR) (IPCC, 1991) dealt with the anthropogenic alteration of the climate system through CO2 emissions, potential impacts, and available cost-effective response measures in terms of mitigation, mainly carbon taxes without much concern for equity issues (IPCC, 2001, WGIII, Chapter 1).

For the Second Assessment Report (SAR), in 1996, Working Groups II and III were reorganized (IPPC, 1996). WGII dealt with adaptation and mitigation. WGIII dealt with the socio-economic cross-cutting issues related to costing climate change's impacts and providing cost-benefit analysis (CBA) for decision-making. Preparation of the SAR formally included NGO and government policy representatives to help overcome the divide between science and policy and help build a shared transparent consensus. The socio-institutional context was emphasized as well as the issues of equity, development, and sustainability (IPCC, 2001, WGIII, Chapter 1)

For the TAR (IPCC, 2001), Working Groups II and III were again reorganized to deal with adaptation and mitigation respectively. The concept of mitigative capacity was introduced and sustainability concerns moved to the center (IPCC, 2001, WGIII, Chapter 1). Four cross-cutting issues were identified: costing methods; uncertainties; decision analysis frameworks; and development, equity and sustainability (IPCC, 2000).

The Fourth Assessment Report (AR IV) summarizes the information contained in previous IPCC reports, including the IPCC special reports on Carbon Capture and Storage, on Safeguarding the

Ozone Layer and the Global Climate System, published since TAR, and assesses the scientific literature published since 2000.
Although the structure AR IV resembles the macro-outline of the TAR, there are distinct differences between them. The AR IV assigns greater weight to (a) a more detailed resolution of sectoral mitigation options and costs, (b) regional differentiation, (c) emphasizing previous and new cross-cutting issues: risks and uncertainties, decision and policy making, costs and potentials, and the relationships between mitigation, adaptation and sustainable development, air pollution and climate, regional aspects and the issues related to the implementation of UNFCCC Article 2, and (d) the integration of all these aspects.

1.5.2 Roadmap

This report assesses options for mitigating climate change. It has four major parts, A-D. Part A includes Chapter 1, an introduction, and Chapter 2, on 'framing issues'. Chapter 2 introduces the reports cross-cutting themes, listed above, and outlines how these themes are treated in subsequent chapters. It introduces important concepts (e.g. cost-benefit analysis and regional integration) and defines important terms used throughout the report.

Part B has one chapter, Chapter 3. It summarizes long-term mitigation scenarios and gaps between various baseline scenarios and different atmospheric GHG stabilization levels. It pays particular attention to the literature on criticism of the IPCC SRES baselines. It discusses driving forces for GHG emissions and mitigation in the short- and medium-terms, and emphasizes the role of technology relative to social, economic and institutional inertia. It examines the relation between adaptation, mitigation and avoided climate change damages in the light of decision-making regarding atmospheric GHG concentrations (Art. 2 UNFCCC).

Part C has seven chapters which assess in sequence mitigation options in different sectors. Chapter 4 addresses the energy supply sector, including carbon capture and storage. Chapter 5 addresses transport and associated infrastructures; Chapter 6 the residential, commercial and service sectors; Chapter 7 the industrial sector including internal recycling and reuse of industrial wastes; Chapters 8 and 9 the agricultural and forestry sectors including land use and biological carbon sequestration; and Chapter 10 waste management, post-consumer recycling and reuse.

These seven chapters use a common template and cover all relevant aspects of GHG mitigation, including costs, policies, technology development, technology transfer, system changes and long-term options. They provide the integrated picture that was absent in the TAR. Where supporting literature is available, they address important differences across regions.

Part D has three chapters (11 to 13) focusing on major cross-sectoral considerations. Chapter 11 assesses the aggregated short/ medium term mitigation potential, macro-economic impacts, economic instruments, technology development and transfer, and cross-border influences (or spill-over effects). Chapter 12 links climate mitigation with sustainable development, and assesses the GHG emission impacts of implementing the Millennium Development Goals and other sustainable development policies and targets. Chapter 13 assesses domestic climate policy instruments and the interaction between domestic climate policies and various forms of international cooperation and reviews climate change as a global commons issue in the context of sustainable development objectives and policies. It summarizes relevant treaties, cooperative development agreements, private-public partnerships and private sector initiatives and their relationship to climate objectives.

References

Akimoto, K., Homma, T., Kosugi, T., Li, X., Tomoda, T. and Fujii, Y.. 2005, Role of CO2 Sequestration by Country for Global Warming Mitigation After 2013, In: Rubin, E.S., Keith, D.W., and Gilboy, C.F. (eds.), Proceedings of the 7th International Conference on Greenhouse Gas Control Technologies: Vol. I, Peer Reviewed Papers and Overviews, 911-920.

Archer, D., and B. Buffett, 2005: Time-dependent response of the global ocean clathrate reservoir to climatic and anthropogenic forcing. Geochem. Geophys. Geosyst., 6

Archer, D., P. Martin, B. Buffett, V. Brovkin, S. Rahmstorf, and A. Ganopolski, 2004: The importance of ocean temperature to global biogeochemistry. Earth and Planetary Science Letters, 222(2), pp. 333-348.

Baker, T., Pan, H., Kohler, J., Warren, R. And Winne, S. 2006, "Avoiding Dangerous Climate Change by Inducing Technological Progress: Scenarios Using a Large-Scale Econometric Model", In: Hans Joachim Schellnhuber (editor in chief) Avoiding Dangerous Climate Change, Cambridge University Press 361-371

Baranzini, A., M. Chesney, and J. Morisset, 2003: The impact of possible climate catastrophes on global warming policy. Energy Policy, 31(8), pp. 691-701.

Barnett, J., and W. Adger, 2003: Climate dangers and atoll countries. Clim. Change, 61(3), pp. 321-337.

Burkett, V.R., D.A. Wilcox, R. Stottlemyer, W. Barrow, D. Fagre, J. Baron, J. Price, J.L. Nielsen, C.D. Allen, and D.L. Peterson, 2005: Nonlinear dynamics in ecosystem response to climatic change: Case studies and policy implications. Ecological Complexity, 2(4), pp. 357-394.

CEU (Council of the European Union), 1996: Climate Change - Council conclusions 8518/96 (Presse 188-G) 25/26. VI.96.. http://ue.eu.int/newsroom/LoadDoc.asp?BID=89&DID=43617&from=&LANG=6.

CEU (Council of the European Union), 2005a: Presidency Conclusions – Brussels, 22 and 23 March 2005 - IV. CLIMATE CHANGE, European Commission, Brussels, Belgium. http://www.eu2005.lu/en/actualites/conseil/2005/03/23conseileuropen/ceconcl.pdf

CEU (Council of the European Union), 2005b: Climate Change: Medium and longer term emission reduction strategies, including targets. Council conclusions Union, European Commission, Brussels, Belgium.. http://ue.eu.int/uedocs/cmsUpload/st07242.en05.pdf

Davidson, O., K. Halsnaes, S. Huq, M. Kok, B. Metz, Y. Sokona, and J. Verhagen, 2003: The development and climate nexus: the case of sub-Saharan Africa. Climate Policy, 3(Supplement 1), pp. S97-S113.

Dessai, S., W. N. Adger, M. Hulme, J. Turnpenny, J. Kohler, and R. Warren (2004), Defining and Experiencing Dangerous Climate Change, Climatic Change, 64, 11

Edenhofer, O., Lessmann, K., Kemfert, C., Grubb, M., Koehler, J., 2006: Induced Technological Change: Exploring its Implications for the Economics of Atmospheric Stabilisation: Synthesis Report from the Innovation Modelling Comparison Exercise. In Edenhofer, O., Carraro, C., Köhler, J., Grubb, M., 2006, Endogenous Technological Change and the Economics of Atmospheric Stabilisation. The Energy Journal, Special Issue

Edmonds, J. 2004, "Climate Change and Energy Technologies", Mitigation and Adaptation Strategies for Global Change, 9(4), 391-416

EEA (European Environment Agency) 2006: EN09_EU-25_Policy_effectiveness (Underpinning Energy and Environment indicator fact-sheets for Energy and environment in the European Union – Tracking progress towards integration, EEA Report No 8/2006), http://reports.eea.europa.eu/eea_report_2006_8/en/factsheets/EN09_EU-25_Policy_effectiveness.pdf, EEA (accessed July, 2006)

EIA (Energy Information Administration), 2006a: http://www.eia.doe.gov/emeu/international/crude1.html, U.S. Department of Energy. Washington, DC 20585

EIA (Energy Information Administration), 2006b: International Energy Outlook 2006. DOE/EIA-0484(2006), www.eia.doe.gov/oiaf/ieo/index.html. U.S. Department of Energy. Washington, DC 20585

Emanuel, K., 2005: Increasing destructiveness of tropical cyclones over the past 30[thinsp]years. Nature, 436(7051), pp. 686-688.

EMF (Energy Modeling Forum), 2004: Energy Modeling Forum Study 21. http://www.stanford.edu/group/EMF

Epstein, P.R., and J.J. McCarthy, 2004: Assessing Climate Stability. Bull. Amer. Meteorol. Soc., 85(12), pp. 1863-1870.

Friedlingstein, P., J.L. Dufresne, P.M. Cox, and P. Rayner, 2003: How positive is the feedback between climate change and the carbon cycle? Tellus Ser. B-Chem. Phys. Meteorol., 55(2), pp. 692-700.

Giorgi, F. (2005). "Climate Change Prediction." Climatic Change 73(3): 239-265.

Giorgi, F., and X. Bi (2005). "Regional changes in surface climate interannual variability for the 21st century from ensembles of global model simulations." Geophysical Research Letters 32(13)

Gleneagles, 2005: The Gleneagles Communique http://www.fco.gov.uk/Files/kfile/PostG8_Gleneagles_Communique,0.pdf, G8 Gleneagles, 2005.

Gregory, J.M., P. Huybrechts, and S.C.B. Raper, 2004: Climatology - Threatened loss of the Greenland ice-sheet. Nature, 428(6983), pp. 616-616.

Gritsevsky, A., and Nakicenovic, N. 2002, “Modelling uncertainty of induced technological change”. In: Grubler, A., Nakicenovic, N., Nordhaus,W.D. (eds.).Technological change and the environment,. Resources for the Future, 251–279.

Hare, W.L., and M. Meinshausen, 2005: How much warming are we committed to and how much can be avoided? Climatic Change, accepted

Higgins, P.A.T., and M. Vellinga, 2004: Ecosystem responses to abrupt climate change: Teleconnections, scale and the hydrological cycle. Clim. Change, 64(1-2), pp. 127-142.

Higgins, P.A.T., and S.H. Schneider, 2005: Long-term potential ecosystem responses to greenhouse gas-induced thermohaline circulation collapse. Global Change Biology, 11(5), pp. 699-709.

Hoegh-Guldberg, O., 2005: Low coral cover in a high-CO 2 world. J. Geophys. Res., 110(C9), pp. 1-11.

Hooss, G., R. Voss, K. Hasselmann, E. Maier-Reimer, and F. Joos, 2001: A nonlinear impulse response model of the coupled carbon cycle- climate system (NICCS). Clim. Dyn., 18(3-4), pp. 189-202.

IEA (International Energy Agency), 2003: Energy to 2050 Scenarios for a Sustainable Future. Paris, France.

IEA (International Energy Agency), 2004: World Energy Outlook 2004. Paris, France.

IEA (International Energy Agency), 2005a. World Energy Outlook 2005: Middle East and North African Insights, Paris, 2005

IEA (International Energy Agency), 2005b. Energy Technologies at the cutting edge. Paris, France.

IEA (International Energy Agency), 2006. R&D Statistics Database, http://www.iea.org/Textbase/stats/rd.asp

Ikeme, J. 2003: ‘Equity, Environmental Justice and Sustainability: Incomplete Approaches in Climate Change Policies’, Global Environmental Change, 13, 195

IPCC (Intergovernmental Panel on climate Change), 1991: The First Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on climate Change), 1996: The Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IPCC, 2000: Guidance papers on the Cross Cutting Issues of the Third Assessment Report of the IPCC. R. Pachauri, T. Taniguchi and K. Tanaka (eds.) IPCC, Geneva, Switzerland.

IPCC, 2001: Climate Change 2001: Mitigation - Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on climate Change), 2005: Special Report on Safeguarding the Ozone Layer and the Global Climate System: issues related to Hydrofluorocarbons and Perfluorocarbons, Cambridge University Press, Cambridge, UK

Janssen, M.A., and B. De Vries, 2000: Climate change policy targets and the role of technological change. Clim. Change, 46(1-2), pp. 1-28.

Jasanoff, S. and B. Wynne, Science and Decision-Making 1998: c.1 in Rayner, S. and E. Malone, ed., Human Choice and Climate Change, Vol. I, Batelle Press 1998.

JISF, 2005; Japan Iron and Steel federation (http://www.jisf.or.jp/en/activity/050715.html)

Jones, C., C. McConnell, K. Coleman, P. Cox, P. Falloon, D. Jenkinson, and D. Powlson, 2005: Global climate change and soil carbon stocks; predictions from two contrasting models for the turnover of organic carbon in soil. Global Change Biol, 11(1), pp. 154-166.

Jones, R., 2004: Managing Climate Change Risks. The Benefits of Climate Change Policies: Analytical and Framework Issues. Corfee-Morlot, J. OECD, Paris.

Kaul, I., I. Grunberg, and M.A. Stern,1999: Global Public Goods, Oxford University Press 1999

Kaul, I., P. Conceiçao, K.,Le Gouven, and R.U. Mendoz, 2003: Providing Global Public Goods, Oxford University Press, 2003

Kaya Y, 1990: Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios. Paper presented to the IPCC Energy and Industry Subgroup, Response Strategies Working Group, Paris.

Knutson, T.R., and R.E. Tuleya, 2004: Impact of CO2-induced warming on simulated hurricane intensity and precipitation: Sensitivity to the choice of climate model and convective parameterization. 18, 3477-3495pp.

Leemans, R., and B. Eickhout, 2004: Another reason for concern: regional and global impacts on ecosystems for different levels of climate change. Global Environmental Change Part A, 14(3), pp. 219-228.

Levermann, A., A. Griesel, M. Hofmann, M. Montoya, and S. Rahmstorf, 2005: Dynamic sea level changes following changes in the thermohaline circulation. Clim. Dyn.

Marland, G., T.A. Boden, and R. J. Andres. 2006. Global, Regional, and National Fossil Fuel CO2 Emissions. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A.

Mastrandrea, M.D., and S.H. Schneider, 2004: Probabilistic Integrated Assessment of "Dangerous" Climate Change. Science, 304(5670), pp. 571-575.

Meehl, G.A., W.M. Washington, W.D. Collins, J.M. Arblaster, A. Hu, L.E. Buja, W.G. Strand, and H. Teng, 2005: How Much More Global Warming and Sea Level Rise? Science, 307(5716), pp. 1769-1772.

Meinshausen, M., W.L. Hare, T.M.L. Wigley, D. van Vuuren, M.G.J. den Elzen, and R. Swart, 2005: Multi-gas emission pathways to meet climate targets. Clim. Change, Accepted, pp. 50.

Nordhaus, D. 2002, “Modeling Induced Innovation in climate-Cjange Policy”, In: Grubler, A., Nakicenovic, N., Nordhaus,W.D. (eds.).Technological change and the environment,.Resources for the Future, 182–209.

Obersteiner, M., C. Azar, P. Kauppi, K. Mollersten, J. Moreira, S. Nilsson, P. Read et al (2001a). "Managing Climate Risk." Science 294(5543): 786b

Obersteiner, M., K, Riahi, C. Azar, R. Mechler, Managing Climate Risk (2001b). International Institute for Applied System Analysis (IIASA), Laxenburg, Austria. IR-01-051, http://www.iiasa.ac.at

OECD (Organization for Economic Cooperation and Development), 2005: Bridge Over Troubled Waters: Linking Climate Change and Development. S. Agrawala (ed). Paris, France.

Olivier, J.G.J., T. Pulles and J.A. van Aardenne (2005a) Part III: Greenhouse gas emissions: 1. Shares and trends in greenhouse gas emissions; 2. Sources and Methods; Greenhouse gas emissions for 1990 and 1995. In: "CO2 emissions from fuel combustion 1971-2003", 2005 Edition, pp. III.1-III.37. International Energy Agency (IEA), Paris. ISBN 9 92-64-10891-2 (paper) 92-64-10893-9 (CD ROM) (2005).

Olivier, J.G.J., Van Aardenne, J.A., Dentener, F., Pagliari, V., Ganzeveld, L.N. and J.A.H.W. Peters (2005b) Recent trends in global greenhouse gas emissions: regional trends 1970-2000 and spatial distribution of key sources in 2000. Env. Sc., 2 (2-3), 81-99. DOI: 10.1080/15693430500400345. http://www.mnp.nl/edgar/global_overview/

O'Neill, B.C., and M. Oppenheimer, 2002: CLIMATE CHANGE: Dangerous Climate Impacts and the Kyoto Protocol. Science, 296(5575), pp. 1971-1972.

Oppenheimer, M., 2005: Defining Dangerous Anthropogenic Interference: The Role of Science, the Limits of Science. Risk Anal., 25(6), pp. 1399-1407.

Oppenheimer, M., and R.B. Alley, 2005: Ice sheets, global warming, and Article 2 of the UNFCCC. Clim. Change, 68(3), pp. 257-267.

Pacala, S. and Socolow, R. (2004), “Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies”, Science Vol. 305, 968-972

Parson, E.A. and H. Ward, 1998: Games and Simulations, in S. Rayner and E. Malone, Eds., Human Choice and Climate Change, Vol. 3, c.2, 105-140, Battelle Press.

Rahmstorf, S., and K. Zickfeld, 2005: Thermohaline circulation changes: A question of risk assessment - An editorial review essay. Clim. Change, 68(1-2), pp. 241-247.

Rijsberman, F.J., and R.J. Swart (eds.), 1990: Targets and Indicators of Climate Change. Stockholm Environment Institute, 1666pp.

Salinger, M., 2005: Climate variability and change: Past, present and future - An overview. Clim. Change, 70(1-2), pp. 9-29.

Scheffer, M.S., S. Carpenter, J.A. Foley, C. Folke, and B. Walker (2001), ‘Catastrophic Shifts in Ecosystems’, Nature, 413, October, p. 591

Senior, C.A., and J.F.B. Mitchell, 2000: The time-dependence of climate sensitivity. Geophys. Res. Lett., 27(17), pp. 2685-2688.

Shindell, D.T., B.P. Walter, and G. Faluvegi, 2004: Impacts of climate change on methane emissions from wetlands. Geophys. Res. Lett., 31(21)

Sperling, F., 2003. Ed. Poverty and Climate Change: Reducing the Vulnerability of the Poor through Adaptation, report by the African Development Bank, UK Department for International Development, Federal Ministry for Economic Cooperation and Development (Germany), Ministry of Foreign Affairs-Development Corporation (Netherlands), OECD, UNDP,UNEP and World Bank, 2003.

Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F.N. Erasmus, M.F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A.T. Peterson, O.L. Phillips, and S.E. Williams, 2004: Extinction risk from climate change. 6970, 145-148pp.

Thuiller, W., S. Lavorel, M.B. Araujo, M.T. Sykes, and I.C. Prentice, 2005: Climate change threats to plant diversity in Europe. PNAS, pp. 0409902102.

Thuiller, W., O. Broennimann, G. Hughes, J.R.M. Alkemade, G.F. Midgley, and F. Corsi, 2006: Vulnerability of African mammals to anthropogenic climate change under conservative land transformation assumptions. Global Change Biology, 12(3), pp. 424-440.

Tokushige, K., Akimoto, K. and Tomoda, T. 2006, Public Acceptance and Risk-benefit Perception of CO2 Geological Storage for Global Warming Mitigation in Japan, Mitigation and Adaptation Strategies for Global Change. forthcoming

Tol, R.S.J., and R. Verheyen, 2004: State responsibility and compensation for climate change damages - a legal and economic assessment. Energy Policy, 32(9), pp. 1109-1130.

Trenberth, K., 2005: Uncertainty in hurricanes and global warming. Science, 308(5729), pp. 1753-1754.

UN (United Nations), 1992: United Nations Framework Convention on Climate Change, United Nations, New York.

UNCED (United Nations Conference on Environment and Development), 1992; Agenda 21, A/CONF.151/26 (Vol. I & II) http://www.un.org/esa/sustdev/documents/agenda21/

UN (United Nations), 2000a; United Nations Millennium Declaration, A/Res/55/2 September 18, 2000

UN (United Nations), 2002b. Report of the World Summit on Sustainable Development, A/CONF.199/20.

UN (United Nations), 2002c. Monterrey Consensus, A/CONF.198/11. http://www.un.org/esa/ffd/aconf198-11.pdf

UNDESA (United Nations Department of Economic and Social Affairs), 2004: United Nations Millennium Development Goals: Progress Report, UN Department of Economic and Social Affairs and the UN Department of Public Information - DPI/2363, October 27, 2004).

Unruh, G.C., and J. Carrillo-Hermosilla, 2006: Globalizing carbon lock-in. Energy Policy, 34(10), pp. 1185-1197.

Vellinga, M. and R.A. Wood, 2002: Global climatic impacts of a collapse of the Atlantic thermohaline circulation. Clim. Change, 54(3), pp. 251-267.

World Bank, 2004: World Development Indicators. The World Bank, Washington, DC, USA.

WRI (World Resources Institute), 2006: Climate Analysis Indicators Tool (CAIT) 3.0. World Resources Institute, Washington, DC., USA. http://cait.wri.org/