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Author(s):	CLAs:	H-Holger Rogner, Dadi Zhou		
	LAs:	Rick Bradley, Philippe Crabbé, Ottmar Edenhofer, Bill Hare, Lambert Kuipers, Mitsusune Yamaguchi		
	CAs:	Hongwei Yang		
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EXECUTIVE SUMMARY

The United Nations Framework Convention on Climate Change (UNFCCC) requires that dangerous climate change be prevented and hence the stabilization of atmospheric greenhouse gas (GHG) concentrations at levels that would achieve this objective. At present the concentrations are generally increasing, especially for carbon dioxide (CO_2) and GHG emissions close to current trends - 1.4 per cent annual growth rate over the last 30 years - are projected to continue. Without major emissions reductions stabilization is nowhere in sight. Global energy demand and supply - the main drivers of GHG emissions - is projected to continue to grow, especially as populous developing countries pursue industrialization. Regional differentiation is important - economic development needs, resource endowments and capacities - mitigative and adaptive - are too different across regions for a one-size fits all approach.

This Chapter places Article 2 of the Convention with its obligation to prevent "dangerous interference with the climate system" in the context of the main conditions imposed on reaching the Convention's objective, "stabilization", such as unthreatened food production or unimpeded sustainable economic development. Any judgment on "dangerous interference" is necessarily a social and political one depending on the level of risk deemed acceptable. There seems to be a convergence in the literature towards an upper limit of 2°C increase in global mean temperature above pre-industrial levels as a cap before entering the zone of dangerous interference but lower and higher temperature values have been argued as well.

The entry into force of the Kyoto Protocol in February 2005 marks a first, though modest step, towards the implementation of Article 2 but its outcome will still be far from reversing the overall GHG emission trends. 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 several-fold and range from compliance of emission mitigation measures with Article 2 conditions of unhindered sustainable economic development, equity and ethics including common but differentiated responsibilities, to the inherent inertia of long-lived infrastructures, the risks of abrupt or catastrophic change, and potential climate irreversibility.

Climate change mitigation is inseparable from sustainable development thus meeting the Millennium Development Goals, and the two are mutually reinforcing. Climate change exacerbates poverty - mitigation reduces vulnerability. 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. This Report follows the Third Assessment Report (TAR) in its organization but assigns greater weight to cross-cutting issues: risks and uncertainties, decision and policy making, costs and potentials, and the relationships between mitigation, adaptation and sustainable development. New cross -cutting issues are F Gases, regional issues, air pollution and climate, UNFCCC Article 2 as well as short-term versus long-term aspects of climate change and mitigation.

1.1 Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) requires the prevention of dangerous interference with the climate system with this being achieved through the stabilization of atmospheric greenhouse gas (GHG) concentrations. Stabilization means harmonizing the co-evolution of two subsystems: the physical climate subsystem and the biosphere subsystem, which interact to form the complex climate system. The biosphere is made of interacting environmental (biotic and abiotic), technological, and socio-economic subsystems. GHG emissions from the biosphere subsystem accumulate in the atmosphere and have long atmospheric lifetimes. The climate system response to increased GHG concentrations occurs over all time scales but is subject to substantial lags (at the scale of centuries) and inertia. CO_2 is the main anthropogenic greenhouse gas and concentrations of this gas cannot be stabilized without drastic emission reductions. Achieving this quickly (time scale of decades) requires rapid changes of both climate and non-climate relevant behaviors laden with cultural significance (Shove *et al.*, 1998); of capital stocks which are costly (socio-economic inertia), if only because of their interactions with the technological sub-systems affected by the need to replace carbon emitting technologies with cleaner and climate friendly technologies (technological inertia) (IPCC, 2001).

1.2 Article 2 of the convention

1.2.1 The article

Article 2 of the UNFCCC specifies the ultimate objective of that 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" (UNFCCC, 1992).

Article 2 has several interrelated elements, which are linked to other parts of the Convention including the definitions in Article 1.1 of adverse effects[1] and Article 3.3 that relates to the application of the precautionary principle in the face of scientific uncertainty. The level of stabilization and the timeframe over which this needs to be achieved in order to "prevent dangerous anthropogenic interference with the climate system" is linked to the set of criteria in its second sentence: unthreatened food production and unimpeded sustainable economic development. Article 2 does not specify exactly what these mean and hence there are many open questions such as whether or not the threat to food production is to be measured nationally, regionally or globally.

Sustainable development in the Article 2 context has two criteria to satisfy: First "to enable economic development" and second "to enable economic development to proceed in a sustainable manner" If climate change adversely affects economic development, then the first criterion is not met. If, for example, very costly mitigation measures were introduced too quickly, the second criterion would be violated.

The assessment of adaptation potentials in each of the areas mentioned in Article 2 is essential for a determination of what level of climate change would result in food production or economic development being threatened, or that would not allow ecosystems to adapt naturally.

If stabilization were achieved in such a way that all of these requirements were met, then it could be said that dangerous anthropogenic interference with the climate system had been prevented. Article 2 could be defined either by some climatic target, such as concentration stabilization at a certain level, which is deemed to prevent dangerous interference with the climate system. Either way, the operationalization of Article 2 for mitigation purposes would rely on the development of emission pathways consistent with whatever metric is chosen to define dangerous climate change.

1.2.2 What is dangerous interference with the climate system?

The concept of danger has an external dimension in terms of policy and an internal one in terms of perception. As with all policies, there is a top down and a bottom-up approach to danger. In the top down

[1] Article 1.1: Adverse effects of climate change" means changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare.

perspective, focus is on expert-determined physical vulnerability while, in the bottom-up approach, it is on individually or institutionally determined social vulnerability. The internal dimension focuses on social, cultural and institutional contexts, and social psychology methodologies (Dessai *et al.,* 2004). An interpretation of Article 2 is thus likely to rely on political and/or legal judgements to synthesize the two perspectives (Tol and Verheyen, 2004) as to what may constitute unacceptable impacts on food production, ecosystem adaptation or economic development. It may also rely on political assessments of the acceptability of the risk of large scale disruptions in the earth system (Friedlingstein *et al.,* 2003; Archer and Buffett, 2005).

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". Research since that time has tended to confirm this assessment for many different ecosystems (see Chapter 19 WGII AR4) but the question remains as to the scale and significance of such risks. For example, Stocker *et al.* (1997) argue that the thermohaline circulation could shut down once atmospheric GHG concentrations exceed 600 ppmv and the global mean temperature exceeds pre-industrial levels by 4°C.

The Third Assessment Report (TAR) (IPCC, 2001) identified five broad reasons for concern relevant to Article 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.

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. 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 (EC, 1996). The EU Environment Council reconfirmed this view in 2005 (EU, 2005a) and this also was adopted by the 25 Heads of Government of the European Union (EU, 2005b).

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, though individual, 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 but with little publicly available documentation detailing the reasoning behind the adopted views.

1.2.3 Time scales of climate system responses in relation to the time scales for mitigation and adaptation

Both the climate system and human socioeconomic systems exhibit considerable inertia over different time scales. Whilst a large part of the atmospheric response to forcing changes is on decadal timescales (Hooss *et al.,* 2001) a substantial component appears to be linked to the century time scales of the oceanic response to forcing changes (Senior and Mitchell, 2000). In other words once GHG concentrations are stabilized global mean temperature will soon also stabilize -a slight increase may still occur over several centuries (Hare and

Meinshausen, 2005; Meehl *et al.,* 2005). Sea level rise would however continue for many centuries after GHG stabilization.

Mitigation measures also have a range of time scales with overall, but not precisely defined limits to how fast mitigation measures can act - i.e., the time scales are linked to technological, social, economic, demographic and political factors. Inertia is characteristic of the energy system and this inertia is highly relevant to how fast greenhouse gas concentrations can be stabilized

Adaptation measures typically have shorter timescales than the climate system or many mitigation measures. Over the next 20 years or so even the most aggressive climate policy can do little to avoid warming already 'loaded' into the climate system. Only beyond that time, will benefits from avoided climate change accrue. In broad terms there appear to be several robust implications regarding the operationalisation of Article 2. First, some climate change is inevitable over the next one to three decades given present levels of greenhouse gases and feasible mitigation options. Dealing with these effects of climate change is principally possible via adaptation measures. Second, over longer time frames, beyond the next few decades, mitigation investments have a greater potential to avoid climate change damages compared to unmitigated scenarios and ultimately this potential is larger than the adaptation options presently foreseeable (Jones, 2004).

1.3 Greenhouse gas emission trends

1.3.1 The last three decades

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 3.0 database (Olivier *et al.* 2002) contains global emission trends by broad sectors from 1970-2000[2]. Since 1970 emissions of greenhouse gases (not including ozone depleting substances (ODS) controlled by the Montreal Protocol) have increased by more than 50%, with CO_2 being the largest source having grown by about 60% (see Figure 1.1). 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 1970-2000 period (Figure 1.2). Methane emissions rose by about 25% from 1970, with a 60% 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 about the same proportion as CO_2 emissions, mainly due to increased use of fertilizer and the growth of agriculture. Industrial emission of N_2O fell during this period. Emission of the F-gases grew rapidly over the 1990s as they replaced ODS and were estimated to make up about 1.2% of emissions on 100 year GW_p basis in 2000.

[INSERT **Figure 1.1** here]

According to the Edgar 3.0 database in 2000 about 70% of GHG emissions arose from fossil fuel use, about 15% from agriculture, 6% from deforestation, 1.1% from F-gases, and about 8% from industrial, waste and other sources (Figure 1.3). These figures should be seen as indicative. The UNFCCC reporting system for the Annex I parties provides 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.

[INSERT **Figure 1.2** here]

[INSERT **Figure 1.3** here]

[INSERT **Table 1.1** here]

[2] Data to 2000 taken from http://arch.rivm.nl/env/int/coredata/edgar/.

On a geographic basis, there are important differences between regions in energy related CO_2 emissions over the last three decades. Figure 1.4 (IEA, 2005) shows that North America, China, Asia and the Middle East have driven the rise in emissions since 1972. The former USSR region has shown significant reductions since 1990 reaching a level slightly lower than the region had in 1972.

[INSERT **Figure 1.4** here]

1.3.2 Energy and emission trends: the next thirty years

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. As one example, the IEA's World Energy Outlook 2004 (IEA, 2004) takes as its reference case the policies that were in place as of the middle of 2004. Should there be no change in energy policies, and most certainly there will be, the energy mix supplied to run the global economy of 2030 will essentially remain unchanged. In other words, the energy economy may evolve, but not radically change unless policies change. Fossil fuels will still provide the bulk of the world's energy services.

According to the IEA projection, coal (1.5% p.a.), oil (1.6% p.a.) and natural gas (2.3% p.a.) all continue to grow in the period up to 2030. Among the non-fossil fuels, nuclear (0.4% 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.) also continue to grow over the forecast 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.

There is a particularly dramatic geographic shift in energy demand as two-thirds of the energy demand growth over this period originates in developing countries. Their share increases for all fuels except for non-hydro renewables.

Global growth in fossil fuel demand has a significant effect on carbon emissions growth - a 62% growth over 2002 levels. This is an annual growth rate of 1.7%. As the bulk of energy demand growth occurs in developing countries, the emissions growth accordingly is dominated by developing countries.

1.3.3 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 1.44% p.a is the result of (see Figure 1.5): Population growth: 1.58% p.a.; GDP/cap[3]*:*1.51% p.a; Energy-intensity: -1.17% p.a.; and Carbon-intensity: -0.47% p.a.

[INSERT **Figure 1.5** here]

The decarbonisation was highest in the OECD economies but the effect was only a reduction in the growth rate of CO_2 emissions. The declining carbon-intensity in the OECD was mainly a by-product of a structural change towards less energy intensive production processes and fuel switching to lower carbon intensive fuels, e.g., from coal to gas and oil or from coal and oil to nuclear and hydro for electricity generation.

Globally, the declining carbon and energy intensities could not offset population growth and income effects, thus carbon emissions are on the rise. And where regional carbon emissions actually declined, the regional economy had first deteriorated. Therefore the task at hand is formidable: global GHG emission reductions in

[3] Purchasing power parity (PPP) at 2000 prices & exchange rates.

absolute terms. This presupposes a reduction of energy and carbon intensities at a faster rate than income and population growth together. Admittedly, there are many possible combinations of the four Kaya identity components. However, Article 2 calls for unimpeded sustainable economic development and. there is an ongoing debate about the scope and the legitimacy of controlling population development. Therefore, the remaining two technology-oriented factors- energy and carbon intensities have to bear the main burden.

1.4 Where do we stand?

1.4.1 UNFCCC and its Kyoto Protocol

The UNFCCC was signed in 1992 by 166 countries at the Rio Earth Summit with entry into force in March 1994. Meanwhile the Convention has been ratified by 188 countries and the European Community. UNFCCC pursues its major objective - the implementation of Article 2 based on several principles laid down in other Articles of the Convention, e.g., differentiated responsibilities and that developed countries lead the mitigation process (Article 3.1), adoption of the precautionary principle including cost-effectiveness (Article 3.3), keeping of inventories of GHG sources and sinks, formulation and regular update of national programmes for both mitigation and adaptation, and development and transfer of relevant technologies by OECD countries (Article 4.1).

The Kyoto Protocol to the UNFCCC was signed in 1997 by 84 countries (including Australia and the United States of America). Ratification required that 55 UNFCCC parties representing collectively 55% of the 1990 Annex 1 countries' GHG emissions ratify the Protocol (Article 25.1). It was ratified by 153 nations (excluding Australia and the United States), representing 61.6 % of the 1990 emissions and entered into force on 16 February 2005. Parties included in Annex B to the Protocol are expected collectively to reduce their GHG emissions (i.e. the six gases listed in Annex A of the Protocol) by 5.2% with respect to 1990 over the commitment period 2008-2012 (Article 3.1) and to make demonstrable progress towards this goal by 2005 (Article 3.2). Each Annex B Party is assigned a quantified GHG emission limitation listed in this Annex of the Protocol. A key feature of the Protocol is the establishment of an international trading system, although domestic action should constitute a "significant element of the effort'' (Article 6.1 (d), Article 17). The Kyoto mechanisms allow Annex B countries to obtain credits for emissions reductions achieved outside their national borders. These mechanisms include the purchase of Assigned Amount Units (AAUs) from trading under Article 17, Emission Reduction Units (ERUs) from project activities under Article 6 from other Annex B Parties, and Certified Emission Reduction Units (CERs) from projects undertaken in developing (non-Annex 1) countries under the Clean Development Mechanism, Article 12). A powerful and relatively intrusive set of procedures for emission monitoring, verification and compliance have been agreed at COP/MOP1 under Articles 5, 7 and 8 and Article 18. The final status of the compliance procedures is to be agreed at COP/MOP1[4].

1.4.2 Sustainable development context

Climate change mitigation is part and parcel of sustainable development and the two are mutually reinforcing. Mitigation conserves or enhances natural capital (ecosystems, environment as sources and sinks for economic activities) and, thereby, contributes to the overall productivity of capital needed for socio-economic development including mitigative and adaptive capacity. In turn, sustainable development paths reduce capital vulnerability to climate change and GHG emissions. Climate change will exacerbate poverty, especially in least-developed countries, which are the most dependent on natural capital (see Chapter 2). Mitigation efforts by developing countries require taking their special circumstances into account.

Sustainable development has environmental, economic and social dimensions. Climate change mitigation satisfies environmental sustainability in that 'stabilization of greenhouse gas concentrations', i.e. climate stabilization, is one of the ultimate goals of UNFCCC (Article 2). Mitigation satisfies economic

[4] Note to reader: This is placeholder pending results from COP/MOP1.

sustainability to the extent that the economic value of natural capital, of which climate is a component, is preserved (strong sustainability) or, at least, the value of aggregate capital (including manufactured, human, natural, and social) is prevented from deteriorating over time (weak sustainability) and maintains the value of consumption. Mitigation satisfies social sustainability as well by paying heed to socio-economic development (rather than simply to growth), to access to resources and freedom, to equity (both inter- and intra-generational), and to organizations and institutions ('rules in use'; Young, 2002). Social sustainability requires the taking into account of the priority needs of developing countries to achieve economic growth and poverty eradication (UNFCCC, 1992, Article 3.4), i.e., countries which may have other development priorities than climate protection (Lomborg, 2004).

Article 3 of UNFCCC specifies additional principles than those listed in Section 1.3.1 which together guide mitigation: intergenerational equity, taking needs and circumstances of developing countries into account especially the most vulnerable ones, policy comprehensiveness, integration of climate into national development policy, openness of trade as support for growth (IPCC, 2001). The equity argument points in the direction of assessing mitigative and adaptive capacity, because vulnerability means degree of exposure to climate risks (IPCC, 2001).

1.4.3 Millennium development goals (MDGs) and Johannesburg plan of implementation (JPOI)

In 2000, heads of state and government of the United-Nations adopted the Millennium Declaration (UN, 2000a) that led to eight MDGs. 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 Article 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 JPOI (UN, 2002a) which explicitly commits the signatories to responsible and equitable management of the earth's resources as part of the broader effort to achieve the MDGs. Building on Agenda 21 (UNCED, 1992), the Plan privileges the first MDG of poverty reduction (Article 6) through, among others, combating desertification and mitigating the effects of future droughts and floods (Article 6. l), and improved access to environmentally sound energy services (Article 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. The Marrakech Accord (UNFCCC, 2001) and the Monterrey Consensus on financing MDGs (UN, 2002b) are reaffirmed, as well as the need to provide technical and financial assistance and capacity building to developing countries (Article 36, c). Article 103.f re-affirms the precautionary principle following UNFCCC Article 3.3 which offers yet another argument in favor of climate change mitigation.

1.4.4 Technology co-operation and transfer

Given the preponderant role played by fossil fuels in global energy supply, it is difficult to imagine meeting the objective of Article 2 of the UNFCCC without technology research, development, demonstration, deployment and diffusion (RDDD&D).

Development and diffusion of new technological systems may take a century (Sanden and Azar, 2005) which explains in part the global interest in early action and implementation of incentives. Diffusion of new and existing technologies will be required both domestically and internationally, in particular to developing countries.

There are various types of technologies under development 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 (Pacala and Socolow, 2004, Neuhoff 2005, Grubb 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.

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.

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 a more effective tool for technology transfer and mitigating GHG emissions.

1.5 Characteristics of the challenge

1.5.1 Irreversibilities

Anthropogenic forcing of the climate system may move it from one stable state to another state. If the perturbation is large enough returning to the original state may be either impossible or extremely difficult and costly (Scheffer *et al.*, 2001; Schneider, 2004). Therefore, climate change may be irreversible. Environmental irreversibility *per se* does not affect abatement policy in a predictable manner. Under uncertainty, it is the combination of environmental irreversibility with other factors that is sufficient for a so-called irreversibility effect to occur (Baker, 2005; Narain *et al.*, 2004; Webster, 2002; Epstein, 1980). The latter means that a decision-maker will adopt a more flexible course of action than would be the case under certainty. These factors are a) inter-temporal separation of decisions, b) the learning structure (Baker, 2005; Kansuntisukmongko, 2004), c) the shapes of marginal abatement and damage cost functions (Baker, 2005); d) the type of spatial correlation among damages (ibid), e) the potentially catastrophic nature of these damages (Cline, 2005), and f) other irreversibilities.

Abatement may take the form of sunk costs in new technologies, which creates another type of irreversibility (reluctance to invest) opposite to the environmental irreversibility. It is impossible to determine a priori which irreversibility will tend to dominate although economic uncertainty seems to matter more than environmental uncertainty (Keller *et al.*, 2004; Pindyck, 2002; Kolstad, 1996).

1.5.2 Public good

Climate is a global public good since it is spatially indivisible, it is freely available to all (non-excludability), and its consumption by one individual (nation) does not diminish its availability to others (non-rivalry). Climate benefits are available to all whether one is willing to assume its preservation costs or not. This does not mean that climate impacts are the same for all. Some countries may actually benefit temporarily from climate change (Reilly *et al.*, 2003).

Mitigation costs are exclusive to the extent that they may be borne by some individuals (nations) while others evade them (free-riding). 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 efforts (costs) decrease with efficient mitigation actions undertaken by others. Without cooperation among all climate beneficiaries, mitigation is not cost-effective and the market fails to allocate mitigation costs efficiently. Because of its additive nature, the larger the number of participants, the smaller the individual cost of providing the public good, i.e., GHG stabilization.

The unequal distribution of (a) stable climate benefits (skewed towards the least-developed countries) and (b) the ability to pay (skewed towards developed countries) may deter participation from the least well off net beneficiaries or from the least wealthy ones with different spending priorities. These distributional inequalities require information sharing and compensation. In a strategic environment, leadership from a significant player (GHG emitter) provides incentives for others to follow suit by lowering their costs (Grasso, 2004; ODS, 2002).

Mitigative and adaptive capacities are public goods as well. Without a concerted effort to shore them up, their levels will be insufficient.

1.5.3 Inertia

Ambitious climate protection goals require new investments in climate friendly technologies (efficiency improvements, renewables, nuclear power) or end-of-pipe-technologies (e.g., carbon capture and storage). From an economic point of view these investments are essentially irreversible. Therefore, in the presence of uncertainty concerning future policy towards GHG emission reduction or stabilisation targets, investors are reluctant to undertake irreversible investments (sunk costs) and investments in carbon-free technologies are postponed (see 1.4.1).

1.5.4 Risk of catastrophe or abrupt change

The possibility of abrupt climate change and/or abrupt changes in the earth system triggered by climate change with potentially catastrophic consequences cannot be ruled out (Budyko, 1999; Higgins *et al*,. 2002; NRC 2002; Alley *et al.*, 2003). Potential examples include the disintegration of the West Antarctic Ice sheet (Oppenheimer and Alley, 2005) which, if it occurred could raise sea level by 4-6 meters over several centuries, 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). Positive feedback from warming may cause the release of carbon or methane from the terrestrial biosphere (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.

1.5.5 Uncertainty

Uncertainty is a steadfast companion when analyzing the climate system, assessing future GHG emissions or the severity of climate change impacts, evaluating these impacts over many generations or estimating mitigation costs. The TAR reported an 'explosion of uncertainties'. Moreover, the terminology concerning risk and uncertainty and its treatment in the literature, including previous IPCC assessments are not consistent (see Chapter 2). Different types of uncertainties have been identified (Manning *et al.*, 2004) and range from value uncertainty related to statistical parameters in a stochastic model or the data themselves, to modeling errors (structural uncertainty) due to a lack of understanding of the factors one is trying to model (relations among variables, functional relationships, etc). Moreover, the model may be incapable of prediction as is standard in complex or chaotic systems (unpredictability).

The use of projections and scenarios is an attempt to overcome unpredictability. Projections are hypothetical trends in driving variables; scenarios are plausible and consistent images about the future chosen among a very large number (a continuum) of possible futures, essentially for their illustrative purpose. One may test policies for sensitivity, robustness, etc. across scenarios. Risks on which no probability can be assigned may be managed through precautionary behavior, real option theory, crisis management, etc. (see Chapter2).

1.5.6 Complexity

The climate system (including physical climate, biosphere, socio-economic, and technological sub-systems) is complex, i.e. it gives rise to collective properties, which are specific to the coupling of the sub-systems. It is subject to multiple interactions among sub - systems, some stabilizing (negative feedbacks), some destabilizing (positive feedbacks), some uncertain, which give rise to a richness of possible behaviors.

The climate system is non-linear in important ways, which means that changes may not always be proportional to the original forcing (greenhouse gas increases or decreases): this can give rise to abrupt changes, surprises, i.e., abrupt responses to climate change or low probability high consequence events. (Higgins et al., 2002; Rial et al., 2004; Schneider, 2004). Its spatial-temporal scope covers several generations and regions over which society's perceptions of what is dangerous are likely to vary and are, therefore, uncertain. (Obersteiner et al, 2001a, 2001b). There is a time - lag between the time when mitigation is applied and the change in GHG concentrations, yet another uncertainty. Properties such as these, quite apart from uncertainty in our knowledge of the climate system or of future greenhouse gas emissions, make it difficult to predict exact changes in the global and regional climate systems due to greenhouse gas emissions (Giorgi 2005; Giorgi and Bi 2005). Notwithstanding these uncertainties, it appears that mitigation will reduce the risk of both global mean and regional changes and the risk of abrupt changes in the climate system (Obersteiner et al. 2001a, 2001b) and that a "precautionary and anticipatory risk management" approach should incorporate adaptation and preventive mitigation (Obersteiner et al. 2001a, 2001b)

The complex nature of the climate change issue, where predictions are not possible, is one of the reasons why scenarios are used to characterize different plausible pathways into the future involving the technological, social and economic evolution of the human system and to quantify the drivers of climate change.

1.5.7 Equity and ethics

There are two broad ethical frameworks for equity: deontology (rights-based, concern for procedures and for individual interest) and consequentiality (outcome or goal-based, concern for society's interest). 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. Equity exhibits preventative (avoid damage inflicted on others), retributive (sanctions), and corrective elements (e.g., 'common but differentiated responsibilities') (Ikeme, 2003a).

The South, more deontological in its approach, tends to favour corrective equity, distributive justice (parity, i.e., equal rights to emissions), retributive equity (ecological debt repaid through emission trading), and procedural equity (broad participation). Procedural equity, i.e. the means by which an outcome is reached must be considered fair and reasonable, may well lead to unequal outcomes if historical responsibilities for cumulative emissions or the inheritance of assets and liabilities by future generations are taken into account (Thompson *et al.*, 1998).

The North, being more consequentialist, favors a sharing of benefits and costs so as to minimize overall costs and maximize global welfare. Resource transfers to the South are based on caring, especially for the poor, and not on an ecological debt (Ikeme, 2003b).

1.5.8 Regional differences

The Kaya-identity as applied to the world (see Section 1.2.3) conceals the fact that the evolution of its driving forces varied considerably across different world regions. The population growth was highest in Africa and Latin America and lowest in Western Europe and US. Over the last three decades, GDP per capita decreased in Africa, was moderate in Latin America, and was strong in Europe and North America. Historically, global income per capita and population growth were partly compensated by decreasing primary energy-intensities. Against this global development, Africa and Latin America experienced increasing energy intensities whereas energy intensities declined in East Asia, North America and Western Europe. The capacity of mitigation of and adaptation to climate change depends on a country's economic development level. When the basic needs for food and shelter have not been met properly, the capacity and resources to effectively respond to climate change in developing countries are far from sufficient. This is more severe and obvious in low-income countries when the gap of per capita income between high income and low income countries has enlarged during the recent three decades[5].

1.6 Framing issues

An authoritative assessment of climate change mitigation options commands not only clear and unambiguous definitions, concepts, objectives and boundaries but also a comprehension of the framing issues. Framing issues are the product of organizational mandates, the interests of key actors, and of policy initiatives into which climate change matters may be tied in a synergistic fashion with an above average probability to obtain stakeholders' support (Young, 2002). Thus, framing issues are not entirely determined by the objective characteristics of the relevant problem at hand. The perception of climate change of individuals and societies are based on psychological, social, ethical, institutional and cultural processes with which scientific information interacts, and also on personal experience, values, information, cognitive processes, and trust. Framing requires surfacing hidden assumptions, black box types of methodologies and unstated issues. In this assessment report, the main framing issues are mainstreaming climate change mitigation as an integral part of sustainable development, the highest possible geographical resolution of mitigation options, costs (private and social) and potentials (economic, market, technical) including associated uncertainties and risks as well as the stage of technology maturity and technology diffusion between North-South and South-South. Further issues include the integration of adaptive and mitigative capacity and the underlying institutional and social structures and equity aspects. Transparency, internal consistency and quantification of assumptions, uniformity in the use of terminology throughout the report and openness and clarity in the presentation of findings and recommendations help convey the essential message to policy makers and embed the proposed action into the ultimate objective of the climate change convention.

1.7 Cross-cutting issues

1.7.1 Relationship between mitigation and adaptation and sustainable development

Adaptation and mitigation are two sets of policy responses to climate change, which can be complementary, substitutable or independent of each other. If adaptation and mitigation are not independent, separation may result in an undervaluation of the net benefits of risk-reducing activities, thus to a lower than required level (Kane and Shogren, 2000). Moreover, risks may be transferred from one collectivity to another, if mitigation and adaptation efforts are incompatible with the ones taken by another collectivity.

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 (Yohe and Tol, 2002). 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, especially at the regional level as climate change impacts and vulnerabilities tend to be regional (e.g., McKibbin *et al.*, 2002).

Both adaptation and mitigation depend on capital assets, including social capital, and affect capital vulnerability and GHG emissions. Through this mutual dependence, both are tied to sustainable development (see Section 1.3.2). Both mitigative and adaptive capacity depend on a number of factors such as available technological options, all forms of capital, access to risk-hedging instruments, the ability of decision-makers to access relevant information and to process the latter in a credible fashion, decision-makers' own credibility and the public's perception of the causality between climate change and its manifestations. Which response to adopt and when to adopt is very much dictated by the sustainable development agenda to the

[5] World Bank: World Development Indicator 2003.

point that sustainable development policies may be the most effective mitigation and adaptation policies. Enhancing mitigative and adaptive capacity is the best risk-hedging policy. Both capacities evolve over time and understanding the determinants of their dynamics is important (Adger *et al.*, 2001; Tol *et al.*, 2004).

1.7.2 Risk and uncertainties

One of the major sources of uncertainties regarding the magnitude of future climate change and associated risks are future GHG emissions released to the atmosphere (see also Chapter 2.3). These are inherently unpredictable and, in the presence of uncertainty, scenarios are a useful approach for illustrating a range of possible future and more importantly the constellation of conditions that could bring them about. Scenarios - consistent images of how the future may unfold - embrace numerous assumptions on the future development of key drivers of emissions such a demographics, economic activity, structural change, innovation and technology change, costs and prices, policy and social preferences. Each of these drivers has its own uncertainties and when combined in a quasi causal chain usually generates an "uncertainty explosion", i.e., large uncertainties concerning the probability of occurrence of a specific scenario. As a result, quantification with any range of uncertainty can be entirely subjective (Manning *et al.*, 2004).

Even if uncertainties are large or subjective, they are not necessarily distributed evenly throughout the domain of GHG mitigation. The performance of some technologies or mitigation measures are better known than others and lend themselves to quantification, as are short-term options compared with more distant ones. In this report, therefore, uncertainties are quantified whenever possible and supported by the literature. The importance of the use of a common and consistent terminology describing uncertainty and risk throughout the report cannot be overemphasized and all possible efforts have been undertaken to that extent based on the guidance notes developed for this purpose (Manning, *et al.*, 2005). Still, climate change mitigation remains decision making under uncertainty. Given the long lead times of mitigation action, fully resolving uncertainties would make an adequate response infeasible (IPCC, 2001). Thus, uncertainty often increases rather than decreases the rational for early preventative action. Moreover, the fact that future emissions are uncertain is less important than the fact that they are, to a large extent, a matter of economic choice.

1.7.3 Costs, technologies and potentials

Unless otherwise stated, through this report costs are given in US dollars at prices and exchange rates of the year 2000. For reasons of comparing different mitigation options on a level playing field, boundaries need to be clearly defined, i.e., what is included in the costs: overnight costs, life cycle costs, discount and interest rates, location factors, life times, etc. While such information is usually available in a consistent manner for a particular study, this is not the case for the numerous studies found in the literature underlying this report. These studies embrace vastly different assumptions on each of these parameters and comparisons of different study results cannot be made in any straightforward fashion. This report, therefore, provides cost or mitigation ranges reflecting the breadth of information available in the literature and summarizes the main factors determining the cost or mitigation range.

The future performance and market penetration of new and advanced technologies in these studies are shaped by varying scenario assumptions related to innovation and technology change as well as to the presence of effective policy. As much as possible, the report will highlight robust technology performance expectations and explain, where appropriate, the reasons for the ranges found in the literature.

Investments in technologies and practices that could reduce GHG emissions are often hampered by barriers ranging from lack of information, trade barriers, market failures due to wrong price signals, to social norms, individual habits, life styles and vested interests which reduce the potentials for GHG mitigation (IPCC, 2001). The TAR identified five categories of increasing mitigation potentials: market, economic, socio-economic, technological and physical potential. At any point in time, the market potential represents the actual use of a technology or practice. The removal of barriers such as market or institutional imperfections would results in an expansion of cost-effective mitigation technologies and open up the economic potential, i.e., all options that are cost-effective from the consumers' point of view are implemented. Changing consumer preferences and life styles towards “climate responsible behaviour” push the mitigation envelope even further towards the realization of the socio-economic potential, i.e., all cost effective measures are being implemented. Reducing the costs of non-cost effective or unaffordable mitigation options makes the technological potential accessible. The final category physical potential represents the theoretical upper limit. The boundaries between these potentials are not fixed or constant but are in flux as a result of changing relative costs and prices, innovation, policy and behaviour. Reference to mitigation potentials in this report, therefore, unambiguously specifies category and temporal scope of the potential.

1.7.4 Policy, governance and decision making

Typical climate policies include direct regulations and standards, economic incentives (carbon tax, tradable permits, hybrid of these, i.e. tradable permits with a safety valve, and subsidies), voluntary agreements and others (such as R&D, public procurement etc.). Sometimes, policies for other purposes (for example liberalization of energy regulations) may contribute to GHG emissions reduction. Most of these policies can be introduced both nationally and internationally, having their own pros and cons as discussed in the following chapters. The most frequently used criteria for policy evaluation are: environmental effectiveness, economic efficiency, equity, administrative and political feasibility and impact on technological change.

From the governance point of view, international policy is made through, in many cases, multilateral environmental agreements (MEAs). Their effectiveness depends on the factors both within and outside the scheme. To avoid free riders and to invite as many participants as possible, many MEAs frequently include financial and technological incentives (carrots) and trade restrictions (sticks). Also, for MEAs to be effective, major stakeholders should participate and act within the scheme. A recent innovation in the context of the Kyoto Protocol is the introduction of trading in order to lower costs and a powerful emission monitoring, verification and compliance system that can both encourage compliance (through triggers allowing or disallowing trading) and also rectify cases of non-compliance.

Decision-making tools include; cost benefit analysis (policy to be undertaken as long as benefit exceeds cost), cost effectiveness analysis (comparison of costs for attaining given targets), multi-criteria-analysis (integrating different decision parameters not necessarily with monetary values attached), portfolio analysis (portfolio of policies that have different returns and risks) etc. One must bear in mind, however, the complex nature of decision-makings in climate change due to the very characteristics of climate change, i.e. intergenerational, uncertain and catastrophic. Also the difficulty to measure environmental damages in monetary values should be taken into account.

1.7.5 Regional issues

The energy use per capita in developing countries is still fractions of the per capita levels in the industrialized countries. For example, the levels in China (0.726 toe) and India (0.316 toe) are much smaller than that in United States (8.0 toe), Canada (7.98 toe), Japan (4.1 toe) and OECD Europe (3.44 toe). Recent studies (Zhou *et al.*, 2004; Yang, 2004; Yang and Xu, 2003; Yang *et al.* 2001) show that developing countries need and will take active measures towards the implementation of their national sustainable development objectives, i.e., to coordinate and integrate economic development, energy supply based on their national resource endowment and accessibility of energy resources, and environmental protection. To achieve the multiple objectives of economic development, poverty alleviation, providing affordable energy services, reducing the population without electricity access, and improving the environment, will to a large extent depend on technology innovation and diffusion. Efforts towards achieving sustainable development will benefit the global economic development and lead to a further decline in energy-income elasticities.

1.7.6 Air pollution and climate

Energy production and use is a major source of air pollution. Projected future levels of air pollutants if realized present major problems for crops and health in different regions of the world (Chameides *et al.*, 1999; Prather *et al.*, 2003; Kan *et al.*, 2004). Air pollution enters the climate issue in at least three main, interacting ways. Firstly air pollutants, or their by products, can have an effect, directly or indirectly, on the climate system and can change climate regionally and globally. Secondly, mitigation of greenhouse gases will usually also reduce air pollution emissions, which in some cases will act to reduce radiative forcing of climate change and in others act to increase it (see Table 1.2). Thirdly climate change can also act to affect air pollution levels through changes in atmospheric chemistry, stability and circulation. Adverse regional changes in air pollutants such as tropospheric ozone and other air pollutants (Mickley *et al.*, 2004) with negative effects on human health (Knowlton *et al.*, 2004) are projected. For example, the interaction between the high temperatures and air pollution levels apparently contributed to the death toll caused by the 2003 European heat wave (Fischer *et al.*, 2004).

[Insert **Table 1.2** here]

In short, greenhouse gas mitigation can have a substantial array of co-benefits (ancillary benefits) in relation to the reduction of air pollutants resulting from GHG mitigation policies. Numerous studies from, for example, the USA (Burtraw *et al.*, 2003; Morgenstern *et al.*, 2004), Europe (Alcamo *et al.*, 2002; van Minnen *et al.*, 2002), India (Smith *et al.*, 2000; Venkataraman *et al.*, 2005) and China (Aunan *et al.*, 2004; Streets and Aunan, 2005) demonstrate that there are significant benefits in this area. The European studies show that the costs of achieving existing air pollution standards are lowered when considered in the context of GHG reduction policies.

1.7.7 Fluorinated gases

Where this report deals with fluorinated gases, it concerns not only the Kyoto basket gases, but also Ozone Depleting Substances (ODS, i.e., CFCs and HCFCs) that many of them replace, wherever the emissions of the latter are or will be climate relevant. The most abundant of the fluorinated gases used as ODS replacements, the hydrofluorocarbons, are used in sectors where their unique thermal and safety properties add value in such applications as refrigeration equipment and as blowing agents in foams. Perfluorinated gases have valuable specific properties in a number of mainly industrial applications. Due to the high direct GW_p of the fluorinated gases (for HFCs generally 750-4,000 times that of CO_2, for PFCs much higher, owing to their long lifetimes), emissions are significant. Many PFC uses are immediately emissive, which also applies to a limited number of HFC uses. For the latter, total emissions remain small expressed in CO_2-equivalents compared with the ODS quantities emitted in the past decades and still scheduled to occur in future. Predicting overall environmental impacts is complicated by the fact that several major applications retain the bulk of their fluorinated gases during the lifecycle, resulting in the development of significant banks which, in many instances, can be managed at end-of-life. In some cases, the use of fluorinated gases also increases energy efficiency over the product or equipment lifetime, thereby reducing CO_2 emissions. This may also apply to replacements for fluorinated gases with negligible GW_p which are considered in mitigation scenarios of this report. Use of replacements may have a lower climate impact than the use of fluorinated gases, if considered together with energy related CO_2 emissions, assuming all gases are eventually emitted. Evaluating emission scenarios and the environmental impacts resulting from them, 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. Evaluations will be different for the application sectors considered in this report. A significant review of such assessments was published in an earlier IPCC study (IPCC, 2005). More recent assessments are further evaluated in this report.

1.7.8 Short-term versus long-term

The public discourse on climate change mitigation often focuses on the timing of action. The reality of effective and efficient GHG mitigation is that action is needed now and will be required for at least the next century in order to achieve the objective of Article 2. Cost effective reductions in the near term reduce the risk of exceeding dangerous concentrations and provide time for the introduction of newer, lower emitting technologies that will be required for stabilised concentrations. At the same time, focussing on near term actions and cost can “lock-in” capital that is difficult to remove during its economic lifetime (Sanden and Azar, 2005).

However, it is also clear that the technologies required to fuel the global economy in a world of stabilized concentrations do not exist at competitive prices when compared to existing fossil fuels. Policy responses therefore must include the development of a new generation of technologies. Technology RDD&D is also needed in the near term so that very low levels of GHG emissions can be achieved in the longer term (Sanden and Azar, 2005). The balance cost-effective mitigation policy must find is therefore in the relative commitment of resources to nearer term reductions versus the development of technologies for future reductions, not whether action is required now or later.

1.8 Changes from 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 workplan, 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. These scientists are selected by their governments (Jasanoff *et al.*, 1998).

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

The first assessment report (FAR), in 1990, dealt with the anthropogenic alteration of the climate system, potential impacts and available response measures.

For SAR, in 1996, Working Groups II and III were reorganized. WG II dealt with adaptation and mitigation. WG III dealt with the socio-economic *cross-cutting* issues related to costing climate change’s impacts and providing cost-benefit analysis (CBA) for decision-making (IPCC, 1996). Preparation of the SAR formally included NGO and government policy representatives to help overcame the divide between science and policy and help build a shared transparent consensus.

For TAR, in 2001, Working Groups II and III were again reorganized to deal with adaptation and mitigation respectively. Four cross-cutting issues were identified: costing methods; uncertainties; decision analysis frameworks; and development, equity and sustainability (IPCC, 2000).

The fourth assessment report, due in 2007, follows TAR in its organization but assigns greater weight to the following cross-cutting issues: risks and uncertainties; decision and policy making; costs, including technologies and potentials; and sustainable development, including relationships between mitigation, adaptation and sustainable development. New cross-cutting issues are F gases, regional issues, air pollution and climate, UNFCCC Article 2 as well as short-term versus long-term aspects of climate change and mitigation.

1.9 Stucture of report - road map

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 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 and mitigation in the light of decision-making regarding atmospheric GHG concentrations (Art 2 UNFCCC).

Part C has eight chapters. The first six assess 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 six 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 was available, they address important differences across regions.

Part C’s other two chapters address major cross-sectoral considerations. Chapter 11 assesses the aggregated 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.

Part D has one chapter, Chapter 13. It assesses 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.

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