News from Policy and Legislation

Intergovernmental Panel on Climate Change

IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change 1995*

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1 The UNFCCC Article 2

1.1 Following a resolution of the Executive Council of the World Meteorological Organization (July 1992), the IPCC decided to include an examination of approaches to Article 2, the Objective of the UN Framework Convention on Climate Change (UNFCCC), in its work programme. It organized a workshop on the subject in October 1994 in Fortaleza, Brazil, at the invitation of the Government of Brazil. Thereafter, the IPCC Chairman assembled a team of lead authors (listed at the end of this report) under his chairmanship to draft the Synthesis. The team produced the draft which was submitted for expert and government review and comment. The final draft Synthesis was approved line-by-line by the IPCC at its eleventh session (Rome, 11–15 December 1995), where representatives of 116 governments were present as well as 13 intergovernmental and 25 non-governmental organizations. It may be noted for information that all Member States of the World Meteorological Organization and of the United Nations are Members of the IPCC and can attend its sessions and those of its Working Groups. The Synthesis presents information on the scientific and technical issues related to interpreting Article 2 of the UNFCCC, drawing on the underlying IPCC Second Assessment Report. Since the Synthesis is not simply a summary of the IPCC Second Assessment Report, the Summaries for Policymakers of the three IPCC Working Groups should also be consulted for a summary of the Second Assessment Report:

IPCC Working Group I: 1995 Summary for Policymakers

- Greenhouse gas concentrations have continued to increase
- Anthropogenic aerosols tend to produce negative radiative forcings
- Climate has changed over the past century
- The balance of evidence suggests a discernible human influence on global climate
- Climate is expected to continue to change in the future
- There are still many uncertainties

IPCC Working Group II: 1995 Summary for Policymakers
Impacts, Adaptation and Mitigation Options

IPCC Working Group III: 1995 Summary for Policymakers
The Economic and Social Dimensions of Climate Change

1.2 Scientific and technical assessments of climate change and its impacts have been conducted by the Intergovernmental Panel on Climate Change (IPCC). The First Assessment, published in 1990, provided a scientific and technical base for the UN Framework Convention on Climate Change (FCCC) which was open for signature at the Earth Summit in Rio in 1992.

1.3 The ultimate objective of the FCCC, as expressed in Article 2 is:
"... 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".

1.4 The challenges presented to the policymaker by Article 2 are the determination of what concentrations of greenhouse gases might be regarded as "dangerous anthropogenic interference with the climate system" and the charting of a future which allows for economic development which is sustainable. The purpose of this synthesis report is to provide scientific, technical and socio-economic information that can be used, inter alia, in addressing these challenges. It is based on the 1994 and 1995 reports of the IPCC Working Groups.

2 Anthropogenic Interference with the Climate System

Interference to the Present Day

2.1 In order to understand what constitutes concentrations of greenhouse gases that would prevent dangerous interference with the climate system, it is first necessary to understand current atmospheric concentrations and trends of greenhouse gases, and their consequences (both present and projected) to the climate system.

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[*] Abridged version of the final draft Synthesis.

2.2 The atmospheric concentrations of the greenhouse gases, and among them, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), have grown significantly since pre-industrial times (about 1750 A.D): CO_2 from about 280 to almost 360 ppmv[1], CH_4 from 700 to 1720 ppbv and N_2O from about 275 to about 310 ppbv. These trends can be attributed largely to human activities, mostly fossil fuel use, land-use change and agriculture. Concentrations of other anthropogenic greenhouse gases have also increased. An increase of greenhouse gas concentrations leads on average to an additional warming of the atmosphere and the Earth's surface. Many greenhouse gases remain in the atmosphere – and affect climate – for a long time.

2.3 Tropospheric aerosols resulting from combustion of fossil fuels, biomass burning and other sources have led to a negative direct forcing and possibly also to a negative indirect forcing of a similar magnitude. While the negative forcing is focused in particular regions and subcontinental areas, it can have continental to hemispheric scale effects on climate patterns. Locally, the aerosol forcing can be large enough to more than offset the positive forcing due to greenhouse gases. In contrast to the long-lived greenhouse gases, anthropogenic aerosols are very short-lived in the atmosphere and hence their radiative forcing adjusts rapidly to increases or decreases in emissions.

2.4 Global mean surface temperature has increased by between about 0.3 and 0.6°C since the late 19th century, a change that is unlikely to be entirely natural in origin. The balance of evidence, from changes in global mean surface air temperature and from changes in geographical, seasonal and vertical patterns of atmospheric temperature, suggests a discernible human influence on global climate. There are uncertainties in key factors, including the magnitude and patterns of long-term natural variability. Global sea level has risen by between 10 and 25 cm over the past 100 years and much of the rise may be related to the increase in global mean temperature.

2.5 There are inadequate data to determine whether consistent global changes in climate variability or weather extremes have occurred over the 20th century. On regional scales there is clear evidence of changes in some extremes and climate variability indicators. Some of these changes have been toward greater variability, some have been toward lower variability. However, to-date it has not been possible to firmly establish a clear connection between these regional changes and human activities.

Possible Consequences of Future Interference

2.6 In the absence of mitigation policies or significant technological advances that reduce emissions and/or enhance sinks, concentrations of greenhouse gases and aerosols are expected to grow throughout the next century. The IPCC has developed a range of scenarios, IS92 a–f, of future greenhouse gas and aerosol precursor emissions based on assumptions concerning population and economic growth, land-use, technological changes, energy availability and fuel mix during the period 1990 to 2100[2]. By the year 2100, carbon dioxide emissions under these scenarios are projected to be in the range of about 6 GtC[3] per year, roughly equal to current emissions, to as much as 36 GtC per year, with the lower end of the IPCC range assuming low population and economic growth to 2100. Methane emissions are projected to be in the range 540 to 1170 Tg[4] CH_4 per year (1990 emissions were about 500 Tg CH_4); nitrous oxide emissions are projected to be in the range 14 to 19 Tg N per year (1990 emissions were about 13 Tg N). In all cases, the atmospheric concentrations of greenhouse gases and total radiative forcing continue to increase throughout the simulation period of 1990 to 2100.

2.7 For the mid-range IPCC emission scenario, IS92a, assuming the "best estimate" value of climate sensitivity[5] and including the effects of future increases in aerosol concentrations, models project an increase in global mean surface temperature relative to 1990 of about 2°C by 2100. This estimate is approximately one third lower than the "best estimate" in 1990. This is due primarily to lower emission scenarios (particularly for CO_2 and CFCs), the inclusion of the cooling effect of sulphate aerosols, and improvements in the treatment of the carbon cycle. Combining the lowest IPCC emission scenario (IS92c) with a "low" value of climate sensitivity and including the effects of future changes in aerosol concentrations leads to a projected increase of about 1°C by 2100. The corresponding projection for the highest IPCC scenario (IS92e) combined with a "high" value of climate sensitivity gives a warming of about 3.5°C. In all cases the average rate of warming would probably be greater than any seen in the last 10,000 years, but the actual annual to decadal changes would include considerable natural variability. Regional temperature changes could differ substantially from the global mean value. Because of the thermal inertia of the oceans, only 50–90% of the eventual equilibrium temperature change would have been realised by 2100 and temperature would continue to increase beyond 2100, even if concentration of greenhouse gases were stabilised by that time.

2.8 Average sea level is expected to rise as a result of thermal expansion of the oceans and melting of glaciers and ice-sheets. For the IS92a scenario, assuming the "best estimate" values of climate sensitivity and of ice melt sensitivity to warming, and including the effects of future changes in aerosol concentrations, models project an increase in sea level of about 50 cm from the present to 2100. This estimate is approximately 25% lower than the "best estimate" in 1990 due to the lower temperature projection, but also reflecting improvements in the climate and ice melt models.

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[1] ppmv stands for parts per million by volume; ppbv stands for parts per billion (thousand million) by volume. Values quoted are for 1992

[2] See table SPM-1 in the Summary for Policymakers of IPCC Working Group II

[3] To convert GtC (gigatonnes of carbon or thousand million tonnes of carbon) to mass of carbon dioxide, multiply GtC by 3.67

[4] Tg: teragram is 10^{18} grams and is the same as a gigatonne

[5] In IPCC reports, climate sensitivity usually refers to the long term (equilibrium) change in global mean surface temperature following a doubling of atmospheric equivalent CO_2 concentration. More generally, it refers to the equilibrium change in surface air temperature following a unit change in radiative forcing (°C/Wm^{-2})

Combining the lowest emission scenario (IS92c) with the "low" climate and ice melt sensitivities and including aerosol effects gives a projected sea level rise of about 15 cm from the present to 2100. The corresponding projection for the highest emission scenario (IS92e) combined with "high" climate and ice-melt sensitivities gives a sea level rise of about 95 cm from the present to 2100. Sea level would continue to rise at a similar rate in future centuries beyond 2100, even if concentrations of greenhouse gases were stabilised by that time, and would continue to do so even beyond the time of stabilisation of global mean temperature. Regional sea level changes may differ from the global mean value owing to land movement and ocean current changes.

2.9 Confidence is higher in the hemispheric-to-continental scale projections of coupled atmosphere-ocean climate models than in the regional projections, where confidence remains low. There is more confidence in temperature projections than hydrological changes.

2.10 All model simulations, whether they were forced with increased concentrations of greenhouse gases and aerosols or with increased concentrations of greenhouse gases alone, show the following features: Greater surface warming of the land than of the sea in winter; a maximum surface warming in high northern latitudes in winter, little surface warming over the Arctic in summer; an enhanced global mean hydrological cycle, and increased precipitation and soil moisture in high latitudes in winter. All these changes are associated with identifiable physical mechanisms.

2.11 Warmer temperatures will lead to a more vigorous hydrological cacle; this translates into prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in other places. Several models indicate an increase in precipitation intensity, suggesting a possibility for more extreme rainfall events. Knowledge is currently insufficient to say whether there will be any changes in the occurrence or geographical distribution of severe storms, e.g., tropical cyclones.

2.12 There are many uncertainties and many factors currently limit our ability to project and detect future climate change. Future unexpected, large and rapid climate system changes (as have occurred in the past) are, by their nature, difficult to predict. This implies that future climate changes may also involve "surprises". In particular, these arise from the non-linear nature of the climate system. When rapidly forced, non-linear systems are especially subject to unexpected behaviour. Progress can be made by investigating non-linear processes and sub-components of the climatic system. Examples of such non-linear behaviour include rapid circulation changes in the North Atlantic and feedbacks associated with terrestrial ecosystem changes.

3 Sensitivity and Adaptation of Systems to Climate Change

3.1 This section provides scientific and technical information that can be used, inter alia, in evaluating whether the projected range of plausible impacts constitutes "dangerous anthropogenic interference with the climate system", as referred to in Article 2, and in evaluating adaptation options. However, it is not yet possible to link particular impacts with specific atmospheric concentrations of greenhouse gases.

3.2 Human health, terrestrial and aquatic ecological systems, and socioeconomic systems (e.g., agriculture, forestry, fisheries, and water resources) are all vital to human development and well-being and are all sensitive to both the magnitude and the rate of climate change. Whereas many regions are likely to experince the adverse effects of climate change – some of which are potentially irreversible – some effects of climate change are likely to be beneficial. Hence, different segments of society can expect to confront a variety of changes and the need to adapt to them.

3.3 Human-induced climate change represents an important additional stress, particularly to the many ecological and socioeconomic systems already affected by pollution, increasing resource demands, and non-sustainable management practices. The vulnerability of human health and socioeconomic systems – and, to a lesser extent, ecological systems – depends upon economic circumstances and institutional infrastructure. This implies that systems typically are more vulnerable in developing countries where economic and institutional circumstances are less favourable.

3.4 Although our knowledge has increased significantly during the last decade and qualitative estimates can be developed, quantitative projections of the impacts of climate change on any particular system at any particular location are difficult because regional-scale climate change projections are uncertain; our current understanding of many critical processes is limited; systems are subject to multiple climatic and non-climatic stresses, the interactions of which are not always linear or additive; and very few studies have considered dynamic responses to steadily increasing concentrations of greenhouse gases or the consequences of increases beyond a doubling of equivalent atmospheric CO_2 concentrations.

3.5 Unambiguous detection of climate-induced changes in most ecological and social systems will prove extremely difficult in the coming decades. This is because of the complexity of these systems, their many non-linear feedbacks, and their sensitivity to a large number of climatic and non-climatic factors, all of which are expected to continue to change simultaneously. As future climate extends beyond the boundaries of empirical knowledge (i.e., the documented impacts of climate variation in the past), it becomes more likely that actual outcomes will include surprises and unanticipated rapid changes.

4 Analytical Approach to Stabilization of Atmospheric Concentrations of Greenhouse Gases

4.1 Article 2 of the UN Framework Convention on Climate Change refers explicitly to "stabilization of greenhouse gas concentrations". This section provides information on the relative importance of various greenhouse gases to climate forcing and discusses how greenhouse gas emissions might be varied to achieve stabilization at selected atmospheric concentration levels.

4.2 Carbon dioxide, methane and nitrous oxide have natural as well as anthropogenic origins. The anthropogenic emissions of these gases have contributed about 80% of the additional climate forcing due to greenhouse gases since pre-industrial times (i.e. since about 1750 A.D). The contribution of CO_2 is about 60% of this forcing, about four times that from CH_4.

4.3 Other greenhouse gases include tropospheric ozone (whose chemical precursors include nitrogen oxides, nonmethane hydrocarbons and carbon monoxide), halocarbons[6] (including HCFCs and HFCs) and SF_6. Tropospheric aerosols and tropospheric ozone are inhomogeneously distributed in time and space and their atmospheric lifetimes are short (days to weeks). Sulphate aerosols are amenable to abatement measures and such measures are presumed in the IPCC scenarios.

4.4 Most emission scenarios indicate that, in the absence of mitigation policies, greenhouse gas emissions will continue to rise during the next century and lead to greenhouse gas concentrations that by the year 2100 are projected to change climate more than that projected for twice the pre-industrial concentrations of carbon dioxide.

Stabilization of Greenhouse Gases

4.5 All relevant greenhouse gases need to be considered in addressing stabilisation of greenhouse gas concentrations. First carbon dioxide is considered which, because of its importance and complicated behaviour, needs more detailed consideration than the other greenhouse gases.

Carbon Dioxide

4.6 Carbon dioxide is removed from the atmosphere by a number of processes that operate on different timescales. It has a relatively long residence time in the climate system – of the order of a century or more. If net global anthropogenic emissions[7] (i.e. anthropogenic sources minus anthropogenic sinks) were maintained at current levels (about 7 GtC/yr including emissions from fossil fuel combustion, cement production and land-use change), they would lead to a nearly constant rate of increase in atmospheric concentrations for at least two centuries, reaching about 500 ppmv (approaching twice the pre-industrial concentration of 280 ppmv) by the end of the 21st century. Carbon cycle models show that immediate stabilisation of the concentration of carbon dioxide at its present level could only be achieved through an immediate reduction in its emissions of 50–70% and further reductions thereafter.

4.7 Carbon cycle models have been used to estimate profiles of carbon dioxide emissions for stabilization at various carbon dioxide concentration levels. Such profiles have been generated for an illustrative set of levels: 450, 550, 650, 750 and 1000 ppmv. The steeper the increase in the emissions (hence concentration) in these scenarios, the more quickly is the climate projected to change.

4.8 Any eventual stabilised concentration is governed more by the accumulated anthropogenic carbon dioxide emissions from now until the time of stabilisation, than by the way those emissions change over the period. This means that, for a given stabilised concentration value, higher emissions in early decades require lower emissions later on.

Methane

4.13 Atmospheric methane concentrations adjust to changes in anthropogenic emissions over a period of 9 to 15 years. If the annual methane emissions were immediately reduced by about 30 Tg CH_4 (about 8% of current anthropogenic emissions), methane concentrations would remain at today's levels. If methane emissions were to remain constant at their current levels, its concentration (1720 ppbv in 1994) would rise to about 1820 ppbv over the next 40 years.

Nitrous Oxide

4.14 Nitrous oxide has a long lifetime (about 120 years). In order for the concentration to be stabilized near current levels (312 ppbv in 1994), anthropogenic sources would need to be reduced immediately by more than 50%. If emissions of nitrous oxide were held constant at current levels, its concentration would rise to about 400 ppbv over several hundred years, which would increase its incremental radiative forcing by a factor of four over its current level.

Further Points on Stabilization

4.15 Stabilization of the concentrations of very long-lived gases, such as SF_6 or perfluorocarbons, can only be achieved effectively by stopping emissions.

4.16 The importance of the contribution of CO_2 to climate forcing, relative to that of the other greenhouse gases, increases with time in all of the IS92 emission scenarios (a to f). For example, in the IS92a scenario, the CO_2 contribution increases from the present 60% to about 75% by the year 2100. During the same period, methane and nitrous oxide forcings increase in absolute terms by a factor that ranges between two and three.

4.17 The combined effect of all greenhouse gases in producing radiative forcing is often expressed in terms of the equivalent concentration of carbon dioxide which would produce the same forcing. Because of the effects of the other greenhouse gases, stabilisation at some level of equivalent carbon dioxide concentration implies maintaining carbon dioxide concentration at a lower level.

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[6] Most halocarbons, but neither HFCs nor PFCs, are controlled by the Montreal Protocol and its Adjustments and Amendments.

[7] For the remainder of Section 4, "net global anthropogenic emissions" (i.e. anthropogenic sources minus anthropogenic sinks) will be abbreviated to "emissions".

4.18 The stabilization of greenhouse gas concentrations does not imply that there will be no further climate change. After stabilization is achieved, global mean surface temperature would continue to rise for some centuries and sea level for many centuries.

5 Technology and Policy Options for Mitigation

5.1 The IPCC Second Assessment Report (1995) examines a wide range of approaches to reduce emissions and enhance sinks of greenhouse gases. This section provides technical information on options that could be used to reduce anthropogenic emissions and enhance sinks of the principal greenhouse gases with a view to stabilizing their atmospheric concentrations; however, this analysis does not attempt to quantify potential macroeconomic consequences that may be associated with mitigation.

5.2 Significant reductions in net greenhouse gas emissions are technically possible and can be economically feasible. These reductions can be achieved by utilizing an extensive array of technologies and policy measures that accelerate technology development, diffusion, and transfer in all sectors, including the energy, industry, transportation, residential/commercial and agricultural/forestry sectors.

5.3 The degree to which technical potential and cost-effectiveness are realized is dependent on initiatives to counter lack of information and overcome cultural, institutional, legal, financial and economic barriers which can hinder diffusion of technology or behavioural changes.

5.4 By the year 2100 the world‘s commercial energy system in effect will be replaced at least twice, offering opportunities to change the energy system without premature retirement of capital stock; significant amounts of capital stock in the industrial, commercial, residential, and agricultural/forestry sectors will also be replaced. These cycles of capital replacement provide opportunities to utilize new, better performing technologies.

6 Equity and Social Considerations

6.1 Equity considerations are an important aspect of climate change policy and of the Convention and in achieving sustainable development[8]. Equity involves procedural as well as consequential issues. Procedural issues relate to how decisions are made while consequential issues relate to outcomes. To be effective and to promote cooperation, agreements must be regarded as legitimate, and equity is an important element in gaining legitimacy.

6.2 Procedural equity encompasses process and participation issues. It requires that all Parties be able to participate effectively in international negotiations related to climate change. Appropriate measures to enable developing country Parties to participate effectively in negotiations increase the prospects for achieving effective, lasting, and equitable agreements on how best to address the threat of climate change. Concern about equity and social impacts points the need to build endogenous capabilities and strengthen institutional capacities, particularly in developing countries, to make and implement collective decisions in a legitimate and equitable manner.

6.3 Consequential equity has two components: The distribution of the costs of damages or adaptation and of measures to mitigate climate change. Because countries differ substantially in vulnerability, wealth, capacity, resource endowments, and other factors listed below, unless addressed explicitly, the costs of the damages, adaptation, and mitigation maybe borne inequitably.

6.4 Climate change is likely to impose costs on future generations and on regions where damages occur, including regions with low greenhouse gas emissions. Climate change impacts will be distributed unevenly.

6.5 The intertemporal aspects of climate change policy also raise questions of intergenerational equity because future generations are not able to influence directly the policies being chosen today that could affect their well-being, and because it might not be possible to compensate future generations for consequent reductions in their well-being. Discounting is the principal analytical tool economists use to compare economic effects that occur at different points in time. The choice of discount rate is of crucial technical importance for analyses of climate change policy, because the time horizon is extremely long, and mitigation costs tend to come much earlier than the benefits of avoided damages. The higher the discount rate, the less future benefits and the more current costs matter in the analysis.

6.6 The Convention recognizes in Article 3.1 the principle of common but differentiated responsibilities and respective capabilities. Actions beyond "no regrets[9]" measures impose costs on the present generation. Mitigation policies unavoidably raise issues about how to share the costs. The initial emission limitation intentions of Annex I Parties represent an agreed collective first step of those parties in addressing climate change.

6.7 Equity arguments can support a variety of proposals to distribute mitigation costs. Most of them seem to cluster around or combine approaches: Equal per capita emission allocations and allocations based on incremental departures from national baseline emissions (current or projected). The implications of climate change for developing countries are different from those for developed countries. The former often have different urgent priorities, weaker institutions, and are generally more vulnerable to climate change. However, it is likely that developing countries‘ share of emissions will grow further to meet their social and developmental needs. Greenhouse gas emissions are

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[8] In common language equity means "the quality of being impartial" or "something that is fair and just."

[9] "No regrets" measures are those whose benefits, such as reduced energy costs and reduced emissions of local/regional pollutants equal or exceed their cost to society, *excluding* the benefits of climate change mitigation. They are sometimes known as "measures worth doing anyway."

likely to become increasingly global, even whilst substantial per-capita disparities are likely to remain.

6.8 There are substantial variations both among developed and developing countries that are relevant to the aplication of equity principles to mitigation. These include variations in historical and cumulative emissions, current total and per-capita emissions, emission intensities and economic output, projections of future emissions and factors such as wealth, energy structures, and resource endowments.

6.9 A variety of ethical principles, including the importance of meeting people's basic needs, may be relevant to addressing climate change, but the application of principles developed to guide individual behaviour to relations among states is complex and not straightforward. Climate change policies should not aggravate existing disparities between one region and another nor attempt to redress all equity issues.

7 The Road Forward

7.1 The scientific, technical, economic and social science literature does suggest ways to move forward towards the ultimate objective of the Convention. Possible actions include mitigation of climate change through reductions of emissions of greenhouse gases and enhancement of their removal by sinks, adaptation to observed and/or anticipated climate change, and research, development and demonstration to improve our knowledge of the risks of climate change and possible responses.

7.2 Uncertainties remain which are relevant to judgement of what constitutes dangerous anthropogenic interference with the climate system and what needs to be done to prevent such interference. The literature indicates, however, that significant "no regrets" opportunities are available in most countries and that the risk of aggregate net damage due to climate change, consideration of risk aversion and the precautionary approach, provide rationales for actions beyond "no regrets". The challenge is not to find the best policy today for the next 100 years, but to select a prudent strategy and to adjust it over time in the light of new information.

7.3 The literature suggests that flexible, cost-effective policies relying on economic incentives and instruments as well as coordinated instruments, can considerably reduce mitigation or adaptation costs, or can increase the cost-effectiveness of emission reduction measures. Appropriate long-run signals are required to allow producers and consumers to adapt cost-effectively to constraints on greenhouse gas emissions and to encourage investment, research, development and demonstration.

7.4 Many of the policies and decisions to reduce emissions of greenhouse gases and enhance their sinks, and eventually stabilize their atmospheric concentration, would provide opportunities and challenges for the private and public sectors. A carefully selected portfolio of national and international responses of actions aimed at mitigation, adaptation and improvement of knowledge can reduce the risks posed by climate change to ecosystems, food security, water resources, human health and other natural and socio-economic systems. There are large differences in the cost of reducing greenhouse gas emissions, and enhancing sinks, among countries due to their state of economic development, infrastructure choices, and natural resource base. International cooperation in a framework of bilateral, regional or international agreements could significantly reduce the global costs of reducing emissions and lessening emission leakages. If carried out with care, these responses would help to meet the challenge of climate change and enhance the prospects for sustainable economic development for all peoples and nations.

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