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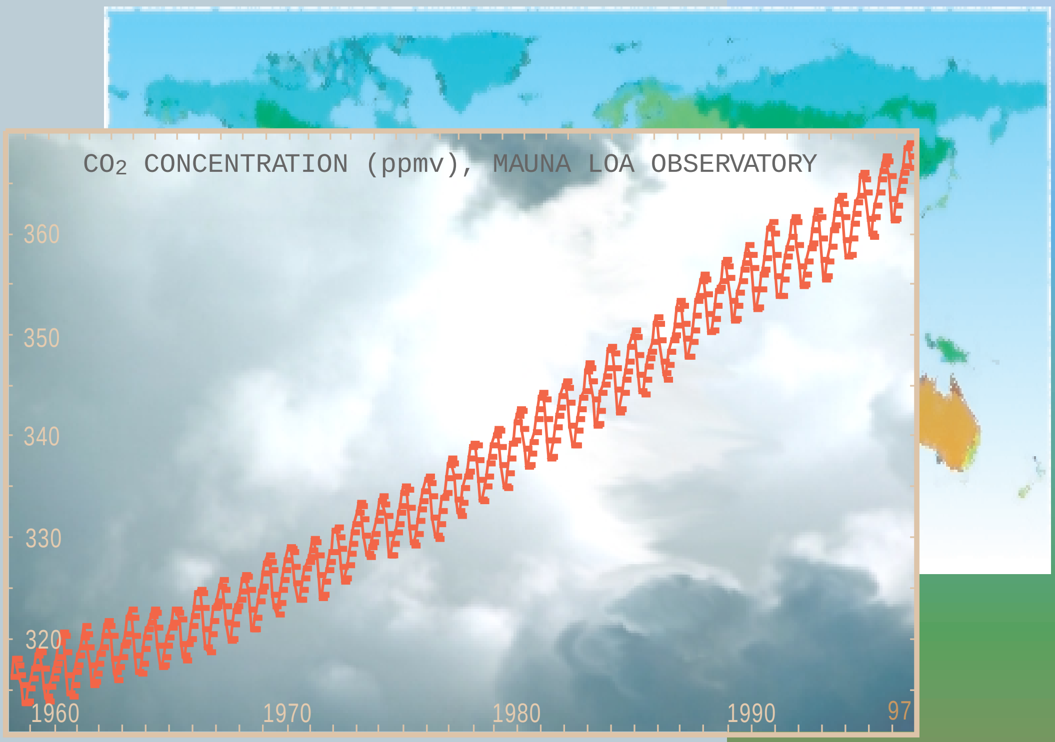

IMPLICATIONS OF PROPOSED CO_2 EMISSIONS LIMITATIONS

IPCC Technical Paper 4

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Implications of Proposed CO_2 Emissions Limitations

Lead Authors

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This is a Technical Paper of the Intergovernmental Panel on Climate Change prepared in response to a request from the United Nations Framework Convention on Climate Change. The material herein has undergone expert and government review, but has not been considered by the Panel for possible acceptance or approval.

October 1997

This paper was prepared under the auspices of IPCC Working Group I, which is co-chaired by Sir John T. Houghton of the United Kingdom and Dr L. Gylvan Meira Filho of Brazil.

Cover: Monthly values of CO_2 concentration (ppmv) from the Mauna Loa Observatory in Hawaii from March 1958 to July 1997, inclusive (data provided by C. D. Keeling and T. P. Whorf, Scripps Institute of Oceanography, University of California at San Diego).

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Contents

Preface

This Intergovernmental Panel on Climate Change (IPCC) Technical Paper on " Implications of Proposed CO_2 Emissions Limitations" is the fourth paper in the IPCC Technical Paper series and was produced in response to a request made by the Subsidiary Body for Scientific and Technological Advice (SBSTA) of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UN/FCCC).

Technical Papers are initiated either at the request of the bodies of the COP, and agreed by the IPCC Bureau, or as decided by the IPCC. They are based on the material already in IPCC Assessment Reports and Special Reports and are written by Lead Authors chosen for the purpose. They undergo a simultaneous expert and government review, followed by a final government review. Comments on this Paper were received from 77 reviewers from 34 countries in the initial review. The Bureau of the IPCC acts in the capacity of an editorial board to ensure that review comments have been adequately addressed by the Lead Authors in the finalization of the Technical Paper.

The Bureau met in its Fourteenth Session (Maldives, 21 September 1997) and considered the major comments received during the final government review. In the light of its observations and requests, the Lead Authors finalized the Technical Paper. The Bureau expressed satisfaction that the agreed Procedures had been followed and authorized the release of the Paper to the SBSTA and thereafter publicly.

We owe a large debt of gratitude to the Lead Authors who gave of their time very generously and who completed the Paper at short notice and according to schedule. We thank the Co-chairmen of Working Group I of the IPCC, John Houghton and Gylvan Meira Filho who oversaw the effort, the staff of the United Kingdom Meteorological Office graphics studio who prepared the figures for publication, Christy Tidd and Lisa Butler who assisted the convening Lead Author in the preparation of the paper and particularly David Griggs, Maria Noguer and Anne Murrill from the IPCC Working Group I Technical Support Unit, for their insistence on adhering to quality and timeliness.

B. Bolin
Chairman of the IPCC

N. Sundararaman
Secretary of the IPCC

Implications of Proposed CO_2 Emissions Limitations

This paper was prepared under the auspices of IPCC Working Group I.

Lead Authors:
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1. INTRODUCTION

1.1 Background

This Technical Paper was produced at the request of the Subsidiary Body for Scientific and Technological Advice (SBSTA) of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UN/FCCC). At its second session (Geneva, 27 February–4 March 1996) SBSTA requested IPCC to provide an assessment of the implications for projected temperature increases, sea level rise and other changes in climate§[1] of different proposals for the limitation of greenhouse gas emissions[2] by Annex I Parties[3]§. The IPCC Bureau approved the production of a Technical Paper in order to meet this request at its tenth session (Geneva, 28–29 March 1996).

An initial problem with the preparation of a useful Technical Paper on this subject was that none of the emissions limitation proposals tabled at that time extended beyond the year 2010. For carbon dioxide (CO_2), even with large emissions differences in 2010, differences in CO_2 concentration, global mean temperature and global mean sea level in 2010 will be comparatively small because of the slow responses of atmospheric CO_2 and the climate and sea level systems to emissions changes. The consequences of greenhouse gas emissions changes, and CO_2 emissions changes in particular, take decades to centuries to manifest themselves fully in the climate system. Thus, in order to carry out useful climate and sea level calculations it is necessary to have information that extends beyond just a few decades. A set of extended emissions limitation scenarios§ were therefore required to enable the analysis to be carried out. It was decided during the twelfth session of the IPCC (Mexico City, 11–13 September 1996) that, to generate information beyond 2010, further guidance was required from SBSTA.

SBSTA considered the issue at its fourth session (Geneva, 16–18 December 1996). By this time, additional emissions limitation proposals had been tabled, compiled in the 31 January 1997 document from the Ad hoc Group on the Berlin Mandate[4] (AGBM) entitled "Framework Compilation of Proposals for Parties for the Elements of a Protocol or Another Legal Instrument (FCCC/AGBM/1997/2)". It is scenarios drawn from these proposals that are studied in more detail in this Technical Paper. In FCCC/AGBM/1997/2 two Parties (France and The Netherlands) made proposals that were open-ended in time-scale. These proposals are suitable for use in a study of the climate and sea level implications of emissions limitations by Annex I countries and, hence, are used as a primary basis for the study in this Technical Paper.

Since the first draft (16 April 1997) of this Paper was written, submissions relevant to this Technical Paper were received from seven Parties to the FCCC (contained in FCCC/SBSTA/1997/MISC2, dated 19 February 1997). These express divergent views on the emissions scenarios to be used. At its fifth session (Geneva, 24–28 February 1997), SBSTA "requested the IPCC to take into account and where appropriate reflect these contributions" in the development of the present Technical Paper (see FCCC/SBSTA/1997/4, paragraph 26(*n*), dated 7 April 1997). These submissions have been considered. Subsequent to this, in an Addendum to the report of the AGBM's sixth session (Bonn, 3–7 March 1997) "Proposals for a Protocol or Another Legal Instrument — Negotiating Text by the Chairman" (FCCC/AGBM/1997/3/Add.1), dated 22 April 1997, there are a number of new proposals and withdrawals. In order to be as responsive as possible to the negotiating process we have therefore included, in Appendix 1, a summary of these latest proposals and how they relate to the emissions limitation proposals studied in more detail in this Technical Paper.

1.2 Scope

This Technical Paper is intended to provide information on the implications of the proposed limitations of Annex I country CO_2 emissions for global CO_2 emissions, and the consequences of these emissions limitations for CO_2 concentration. The Paper also discusses global emissions under the various emissions limitation proposals relative to the requirements for CO_2 concentration stabilization (c.f., Article 2 of the FCCC[5]), and presents the results of calculations for the consequences on the global mean temperature and sea level of the proposed CO_2 emissions limitations.

[1] Hereafter terms with the symbol § can be found in the Glossary (Appendix 4).

[2] Such proposals fall under Article 17 ("Protocols") of the FCCC. We refer to them here as "emissions limitation proposals". These include both the proposals for Annex I countries to limit emissions (as compared to baseline projections) as well as the proposals for absolute reductions of emissions compared to 1990 by Annex I countries. The term Quantified Emission Limitation and Reduction Objectives (QELROs) used by the FCCC has the same meaning, but is less transparent to the general reader. The term "protocol" is not used because this has a broader meaning.

[3] In this Technical Paper, we frequently use the word "countries" to refer to the FCCC term "Parties to the Convention".

[4] The Berlin Mandate: Review of the adequacy of Article 4, paragraph 2(*a*) and (*b*), of the Convention, including proposals related to a protocol and decisions on follow-up.

[5] Article 2 states that "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."

It should be noted that one of the requirements for IPCC Technical Papers is that they must be based solely on material already in the IPCC assessment reports and special reports. The results presented here are therefore consistent with these earlier reports. It should also be noted that, while all the emissions limitation proposals refer only to Annex I countries as agreed upon in the Berlin Mandate (FCCC/CP/1995/7/Add.1, Decision 1/CP.1), dated 6 June 1995, in order to be able to carry out an analysis for global CO_2 concentrations and climate implications it is necessary to use global emissions. Since there are no formal proposals for limitations on emissions from non-Annex I countries, we derive these global values by combining Annex I country emissions under the various limitation proposals with emissions for non-Annex I countries from the "no-climate-policy" IS92*a*, *c*, and *e* scenarios[6] (see Box).

The emissions limitation proposals used in this Paper are expressed variously in terms of CO_2 only or in terms of greenhouse gases. For the purposes of this Paper all the proposals are interpreted as applying to fossil CO_2 emissions§[7] alone. The reasons for using this approximation are given in Section 3.

To fully meet the initial request of the SBSTA (i.e., to discuss the temperature and sea level implications of the emissions limitation proposals) in a comprehensive manner, it would be necessary to cover the full range of possible concentrations (taking into account sinks and sources) of other gases such as methane (CH_4), nitrous oxide (N_2O), tropospheric ozone (O_3) and the halocarbons§, along with the full range of possibilities for sulphate aerosols§ derived from sulphur dioxide (SO_2) emissions. Such an analysis is beyond the scope of this Paper. Further discussion of the effects of various scenarios for other gases and sulphate aerosols is given in IPCC Technical Paper 3[8] (Schimel, *et al.*, 1997).

[6] An alternative but equivalent way to derive global emissions is to first determine the emissions reductions for Annex I countries that result from a particular emissions limitation proposal (this will depend on the IS92 scenario that the limitation proposal is compared with), and to subtract this from the global emissions for the same IS92 scenario.

[7] Fossil CO_2 emissions are those arising from fossil fuel combustion (including gas flaring) and cement production.

[8] Hereafter referred to as TP3: similarly, TP1 and TP2.

IS92 emission scenarios

The six IPCC scenarios, IS92*a-f*, (Leggett, *et al.*, 1992), Supplementary Report to the IPCC Scientific Assessment, hereafter referred to as IPCC92) embody a wide array of assumptions affecting how future greenhouse gas emissions might evolve in the absence of climate policies beyond those already adopted. A summary of the economic growth, energy supply and population projection assumptions made in deriving these scenarios is given in Table 4. The IS92 scenarios take into account:

(*a*) The London Amendments to the Montreal Protocol;
(*b*) Population forecasts of the World Bank and United Nations;
(*c*) The report of the Energy and Industry Subgroup of the IPCC (IPCC-EIS, 1990);
(*d*) Political and economic changes in the former Soviet Union, Eastern Europe and the Middle East; and
(*e*) Data on tropical deforestation and sources and sinks of greenhouse gases.

Overall, the scenarios indicate that greenhouse gas emissions could rise substantially over the coming century in the absence of new and explicit control measures.

IS92*a* and IS92*b*: These scenarios give emission estimates that are intermediate compared with those of the other IS92 scenarios. The major difference between IS92*b* and IS92*a* is that IS92*b* takes into account information available up to 1992 on the commitments of some OECD countries to stabilize their CO_2 emissions.

IS92*c*: This scenario assumes the lowest rate of population and economic growth and severe constraints on fossil fuel supplies. As a result, it is the lowest emission scenario and the only one showing a decreasing emission trend.

IS92*d*: This scenario employs the low population growth rate of IS92*c* but a higher economic growth rate, hence it has the second lowest future emission estimates.

IS92*e*: This scenario assumes intermediate population growth and high economic growth rates with plentiful fossil fuels. Consequently, this scenario has the highest estimates of future emissions.

IS92*f*: This scenario uses the highest population estimates of the IS92 scenarios, but lower economic growth assumptions. It is the second highest emission scenario.

Revised versions of these scenarios are currently being produced by IPCC and will be published as a special report.

The present Technical Paper discusses only the direct effects of the emissions limitation proposals. Therefore, issues such as "carbon leakage", whereby emissions reductions in Annex I countries may have energy price and trade effects which could result in increased emissions in non-Annex I countries, and technology transfer effects, whereby new technology used in Annex I countries could also be used in non-Annex I countries resulting in possible lower emissions in these countries, are not discussed.

2. SUMMARY OF MAIN RESULTS

The key results of this study are as follows:

Emissions

- Emissions by Annex I countries under the French (FR) or Netherlands (NL) emissions limitation proposals are substantially less than emissions under the IS92 scenarios IS92*a*, *b*, *e* and *f* throughout the twenty-first century. Compared with the IS92*c* and *d* scenarios, the differences are small. Relative to the IS92*a* scenario, Annex I country emissions under the limitation proposals represent reductions of 30–90 per cent by the year 2100.

- Even if Annex I countries were to follow the FR or NL limitation proposals, global emissions in 2100 would be two to three times the 1990 level, if non-Annex I country emissions were to grow during 1990–2100 according to the IS92*a* scenario.

Concentration

- When the FR or NL emissions limitation proposals for Annex I countries are combined with IS92 scenarios for non-Annex I countries, projected CO_2 concentrations are less than under any of the IS92 scenarios. The concentration reductions relative to the IS92 scenarios (with the exception of IS92*c*) eventually become substantial, of the order of 100 ppmv by 2100 for IS92*a* and 200 ppmv by 2100 for IS92*e*.

- The effects of emissions limitation proposals accrue only slowly. Relative to the IS92*a* no-limitation case, the concentration reductions for the most extreme of the FR or NL emissions limitation proposals (viz. NL-2%) is only 5 ppmv in 2010, 12 ppmv in 2020 and 22 ppmv in 2030. These numbers represent reductions in the projected concentration increases from 1990 in the absence of intervention of 13 per cent, 19 per cent and 24 per cent, respectively. The percentage influence of the NL-2% limitation proposal rises to 35 per cent by 2100.

- Future CO_2 concentration projections are subject to uncertainties arising from our incomplete understanding of the carbon cycle§. However, uncertainties in the reductions in radiative forcing§ arising from the emissions limitation proposals are smaller. This is because the cumulative emissions reductions due to the limitation proposals are small relative to the total cumulative emissions, and because of the non-linear relationship between CO_2 concentration and radiative forcing.

Stabilization

- None of the emissions limitation proposals would lead to anything approaching CO_2 concentration stabilization when non-Annex I country emissions are assumed to follow the IS92*a* or IS92*e* scenarios. In these cases, CO_2 concentrations range between approximately 575 and 950 ppmv and are still increasing rapidly in the year 2100, at twice (IS92*a*) and five times (IS92*e*) the present rate of increase.

- By 2100, CO_2 concentrations would show a clear tendency towards stabilization if non-Annex I country emissions were to follow the IS92*c* scenario, the lowest of the IPCC emissions scenarios, and Annex I countries were to follow this scenario or any of the FR or NL emissions limitation proposals.

- The previous two key results imply that, for the cases studied, unless population growth, economic growth, technological change and other factors combine in such a way that global emissions mimic the low-emission IS92*c* scenario, substantial global emissions reductions beyond those defined by the various emissions limitation proposals would be required.

- Any eventual stabilized concentration is governed more by the accumulated anthropogenic§ CO_2 emissions from now until the time of stabilization, than by the way those emissions change over the period. This means that, for a given stabilized concentration value, higher emissions in early decades require lower emissions later on.

Temperature and Sea Level

- The emissions limitations proposals considered here affect future changes in global mean temperature and sea level. By 2100, relative to the no-limitation cases, the reduction in global mean temperature increase resulting from the NL-2% limitation proposal ranges between 0.1°C (i.e., from 0.7°C down to 0.6°C for IS92*c* and a climate sensitivity§ of 1.5°C) and 0.9°C (i.e., from 3.9°C down to 3.0°C for IS92*e* and a climate sensitivity of 4.5°C), while the reduction in sea level rise ranges between 2 cm (i.e., from 12 cm down to 10 cm for IS92*c* and a climate sensitivity of 1.5°C) and 15 cm (i.e., from 100 cm down to 85 cm for IS92*e* and a climate sensitivity of 4.5°C).

- While temperature and sea level results are given in detail only for the NL-2% case, the reductions in the increases in these variables achieved by any given year can be easily generalized to other smoothly-varying emissions limitation scenarios.

3. DESCRIPTION AND QUANTIFICATION OF EMISSIONS LIMITATION PROPOSALS

As noted in the Introduction, the emissions limitation proposals for Annex I countries examined in this Technical Paper are documented in the 31 January 1997 report of the AGBM entitled "Framework Compilation of Proposals from Parties for the Elements of a Protocol or Another Legal Instrument" (FCCC/AGBM/1997/2, pp. 34–39). The details (for those suggestions that may be fully defined in quantitative terms) are summarized in Table 1 and expressed in terms of absolute CO_2 emissions in Table 2.

In producing Table 2, emissions limitation suggestions expressed in terms of greenhouse gases (rather than CO_2 specifically) have been interpreted as applying to fossil CO_2 emissions alone. If such limitations were achieved through emissions reductions of non-CO_2 greenhouse gases in addition to, or in place of, CO_2 emissions reductions (i.e., in accordance with the so-called "comprehensive" approach noted in Article 3.3 of the FCCC), then higher CO_2 emissions than those assumed here would be possible. However, if the emissions limitation proposals were expressed in CO_2-equivalent terms (e.g., see TP3, Section 2.2) in an appropriate way, then the temperature and sea level results produced here would apply equally to the CO_2-alone and greenhouse gas (CO_2-equivalent) cases. In the absence of any suggestions for the breakdown between CO_2 and non-CO_2 emissions reductions, and because there is no agreed method of satisfactorily quantifying the effects of non-CO_2 emissions reductions in CO_2-equivalent terms[9], it is not possible to easily quantify the additional CO_2 emissions that a comprehensive approach might allow.

The emissions limitation proposals listed in Table 2 assume that Annex I country emissions levels in the year 2000 are the same as in 1990. This is in accordance with Article 4.2(*a*) and (*b*) of the FCCC. It is also assumed in all cases that CO_2 emissions for Annex I countries remain constant over 1990–2000. If the limitation proposals remain unchanged after the year 2000, the effects of these simplifications on the calculated CO_2 concentrations are very small. Should emissions for Annex I countries rise during the 1990s, then fall to the 1990 level in the year 2000, the increase in concentration in the year 2000 would be approximately 0.4 ppmv for every additional GtC of CO_2 emissions accumulated over 1990–2000 declining to 0.2 ppmv per additional GtC by 2100[10]. Within the range of possible emissions for the 1990s, this effect on concentration is negligible.

[9] Global Warming Potentials (GWPs) provide a means of comparing the effect of different greenhouse gases with that of CO_2. However, the values of the GWPs for a given gas differ greatly depending on the time horizon which is chosen. Therefore GWPs can only be used to provide an approximate measure of CO_2 equivalence associated with a specific choice of time horizon.

[10] The same sensitivity to emissions "errors" over 1990–2000 applies to global emissions. In other words, if global emissions over 1990–2000 differ from the values assumed here, then the effect would be a change in concentration of 0.4 ppmv for each cumulative GtC of emissions "error" in the year 2000, declining to 0.2 ppmv by the year 2100.

Code	*Country (ies) making proposal*	*Emissions limitation proposals for Annex I countries*
AOSIS*	AOSIS	Reduce CO_2 emissions by at least 20 per cent by 2005
AT/DE	Austria, Germany	Reduce CO_2 emissions by 10 per cent by 2005, and by 15–20 per cent by 2010
BE	Belgium	Reduce CO_2 emissions by 10–20 per cent by 2010
DK	Denmark	Reduce CO_2 emissions by 20 per cent by 2005, and by 50 per cent by 2030
CH	Switzerland	Reduce CO_2, N_2O and CH_4 emissions by 10 per cent by 2010
UK	United Kingdom	Reduce ghg emissions by 5–10 per cent by 2010
ZR	Zaire**	Return ghg emissions to 1990 level by 2000, reduce emissions by 10 per cent by 2005, by 15 per cent by 2010, and by 20 per cent by 2020
NL	Netherlands	Reduce ghg emissions by an average of 1–2 per cent per year (from 2000)
FR	France	Reduce per capita ghg emissions by 7–10 per cent over 2000–2010. Reduce per capita ghg emissions to 1.6–2.2 tC/yr by 2100
EU	European Union	Return ghg emissions to 1990 level by 2000 (assumed to apply also to proposals by countries AT/DE, BE, DK, NL and FR)

* Alliance of Small Island States
** Now Democratic Republic of Congo

Table 1. Description of emissions limitation proposals for Annex I countries (FCCC/AGBM/1997/2, dated 31 January 1997). All reductions are relative to the 1990 level. Some proposals apply to CO_2 alone, others to CO_2 plus other greenhouse gases (ghg) presumably in some equivalent CO_2 emissions sense. Note that, in general, FCCC usage of the term ghg excludes gases controlled by the Montreal Protocol.

Code	Country (ies) making proposal	Fossil CO_2 emissions (GtC/yr) for Annex I countries				
		2000	2005	2010	2020	2030
AOSIS	AOSIS	4.59	3.67			
AT/DE	Austria, Germany	4.59	4.13	3.67–3.90		
BE	Belgium	4.59		3.67–4.13		
DK	Denmark	4.59	3.67			2.29
CH	Switzerland	4.59		4.13		
UK	United Kingdom	4.59		4.13–4.36		
ZR	Zaire	4.59	4.13	3.90	3.67	
NL	Netherlands	4.59	4.15–4.37	3.75–4.15	3.06-3.75	2.50–3.40
FR	France	4.59		4.10–4.68		3.49–4.72*

* Linearly interpolated from values in 2010 and 2100

Table 2. Fossil CO_2 emissions (GtC/yr) for Annex I countries under the emissions limitation proposals, based on Table 1 and converted to GtC/yr using 1990 emissions of 4.59 GtC/yr, as given in IPCC92 (Leggett, *et al.*, 1992) and Pepper, *et al.* (1992) and assuming that the 1900 level is equal to the 2000 value. Gaps in this Table indicate that nothing specific was prescribed for that year. More than one value indicates that a range was specified.

If emissions from Annex I countries rose over the 1990s so that their level in the year 2000 exceeded that in 1990 and the higher 2000 level (or some other level) was used as a baseline for future reductions in Annex I country emissions, this would also affect future concentrations. The sensitivity of the concentration projections to such an increase and to the assumed baseline level is, however, relatively small.

The emissions limitation proposals considered here may be divided into two groups (Table 3):

(*a*) Proposals up to 2030 or earlier (AOSIS, AT/DE, BE, DK, CH, UK and ZR). This group contains 10 cases when the low (l) and high (h) cases for the AT/DE, BE and UK proposals are considered individually. However, only five of these are unique (viz. [AOSIS, DK]; [AT/DE-l, BE-l]; [AT/DE-h, ZR]; [BE-h, CH, UK-l] and [UK-h]);

(*b*) Proposals up to 2100 (FR and NL). The FR suggestion is based on per capita emissions. Since conversion to actual emissions requires population estimates, the resulting emissions span a range of possibilities. From these we derive low (FR-Low), central (FR-Central) and high (FR-High) emissions cases that span the range. The NL proposal specifies two extremes, corresponding to 1 per cent and 2 per cent per year compound fossil CO_2 emissions reductions after 2000, identified as NL-1% and NL-2%, respectively. Appendix 2 gives a more detailed description of the FR and NL emissions limitation proposals.

In terms of emissions reductions, the effect of any limitation proposal depends on the baseline from which it is measured. Here we use, to give a range of baselines, the IS92 fossil CO_2 emissions scenarios for Annex I countries. Figure 1 compares these with the FR and NL emissions limitation proposals. The IS92 emission scenarios illustrated here, IS92*a*, *c* and *e*, bracket results for the other three scenarios, IS92*b*, *d* and *f*. Table 4 gives a summary of the economic growth, energy supply and population projection assumptions made in deriving these scenarios. Relative to IS92*a* and IS92*e*, the proposals represent substantial emissions reductions. Relative to IS92*c* the FR-Central and FR-High proposals actually have higher emissions. It should be noted, however, that it is difficult to make a direct comparison between IS92*c* and the FR-Central and FR-High cases because the latter use mid and high (Annex I) population projections, while IS92*c* uses the low (global) population projection (see Table 4). A more consistent comparison is FR-Low and IS92*c*; here the emissions reduction proposal represents a relatively small reduction below the IS92*c* case in terms of cumulative CO_2 emissions. Both NL-1% and NL-2% correspond to reductions below IS92*c*. These are quite substantial (in percentage terms for cumulative emissions) for the NL-2% case.

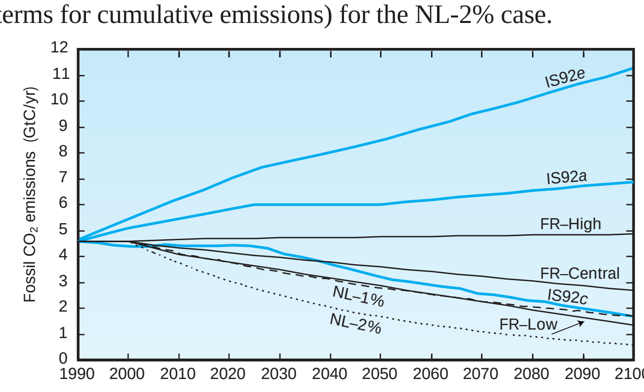

Figure 1. Fossil CO_2 emissions (GtC/yr) for Annex I countries under the French (FR) and Netherlands (NL) emissions limitation proposals compared with those under the IS92*a*, *c* and *e* scenarios. FR-Low, FR-Central and FR-High are derived from a range of possibilities based on per capita emissions. NL-1% and NL-2% refer to 1 per cent and 2 per cent per year compound CO_2 emissions reductions after 2000.

Code	Country (ies) making proposal	Interpolated fossil CO_2 emissions (GtC/yr) for Annex I countries					
		2000	2005	2010	2020	2030	2100
AOSIS	AOSIS	4.59	3.67				
AT/DE-l	Austria, Germany	4.59	4.13	3.67			
AT/DE-h	Austria, Germany	4.59	4.13	3.90			
BE-l	Belgium	4.59	4.13	3.67			
BE-h	Belgium	4.59	4.36	4.13			
DK	Denmark	4.59	3.67	3.40	2.85	2.29	
CH	Switzerland	4.59	4.36	4.13			
UK-l	United Kingdom	4.59	4.36	4.13			
UK-h	United Kingdom	4.59	4.48	4.36			
ZR	Zaire	4.59	4.13	3.90	3.67		
NL-1%	Netherlands	4.59	4.37	4.15	3.75	3.40	1.68
NL-2%	Netherlands	4.59	4.15	3.75	3.06	2.50	0.61
FR-Low	France	4.59	4.34	4.10	3.79	3.49	1.34
FR-Central	France	4.59	4.47	4.34	4.16	3.97	2.69
FR-High	France	4.59	4.63	4.68	4.70	4.72	4.87

Table 3. Interpolated fossil CO_2 emissions (GtC/yr) for Annex I countries under the emissions limitation proposals listed in Table 2. When the low (l) and high (h) cases for AT/DE, BE and UK are considered separately, there are 10 individual shorter-duration proposals (i.e., extending only to 2030 or earlier). However, only five of these are unique (proposal DK is the same as proposal AOSIS to 2005; proposal BE-l is the same as AT/DE-l; proposal ZR is the same as AT/DE-h to 2010; and proposals CH and UK-l are the same as BE-h). NL-1% and NL-2% refer to 1 per cent and 2 per cent per year compound CO_2 emissions reductions after 2000. FR-Low, FR-Central and FR-High are derived from a range of possibilities based on per capita emissions (see Appendix 2).

		Summary of assumptions in the IS92 emissions scenarios				
		IS92a,b	IS92c	IS92d	IS92e	IS92f
Economic growth (1990–2025) (GNP/capita)		2.9%	2.0%	2.7%	3.5%	2.9%
Economic growth (2025–2100) (GNP/capita)		2.02%	0.83%	1.67%	2.77%	2.02%
Energy supply: oil and gas (1990-2100) (EJ)		25 000	15 300	15 300	31 400	31 400
Population projection (bn)		*World Bank*	*UN Med.-Low*	*UN Med.-Low*	*World Bank*	*UN Med.-High*
DEV population	***1990***	1.266	1.266	1.266	1.266	1.266
	2025	1.435	1.340	1.340	1.435	1.579
	2100	1.416	0.840	0.840	1.416	2.215
RoW population	***1990***	3.986	3.986	3.986	3.986	3.986
	2025	6.979	6.251	6.251	6.979	7.866
	2100	9.896	5.575	5.575	9.896	15.377

Table 4. Economic growth, energy supply and population projection assumptions made in the IS92 emissions scenarios from IPCC92 (Leggett, *et al.*, 1992, Tables A3.1 and A3.2). Economic growth is expressed by changes in Gross National Product (GNP) per capita with 2025–2100 values calculated from figures given for 1990–2025 and 1990–2100. Energy supply is for conventional oil and gas for 1990-2100 expressed in exajoules (EJ). For population projections, we use the UN Medium-Low, World Bank and UN Medium-High projections. These projections are expressed in billions (bn). Countries are split into "developed" (DEV) and "rest of world" (RoW) where "developed" is the sum of OECD, USSR and Eastern Europe (1990 categories). Calculations made in this Technical Paper have assumed that these figures apply to Annex I and non-Annex I groupings, a reasonable approximation given inherent uncertainties in the data.

4. GLOBAL CO_2 EMISSIONS UNDER THE EMISSIONS LIMITATION PROPOSALS

To determine global CO_2 emissions under the various emissions limitation proposals, Annex I country emissions for the various limitation cases have been combined with emissions from non-Annex I countries defined by the "no-climate-policy" IS92 scenarios (see Box in Section 1). This approach is consistent with the provision in the Berlin Mandate, which states that the current negotiations under this Mandate "will not introduce any new commitments for Parties not included in Annex I". Figure 2 gives non-Annex I country emissions for IS92*a*, *c* and *e*, obtained by subtracting Annex I values (Figure 1) from global emissions[11] values given in IPCC92 (Leggett, *et al.*, 1992) and Pepper, *et al.* (1992).

Figure 3 gives global fossil CO_2 emissions out to 2030 where Annex I country emissions follow the various limitation proposals and non-Annex I country emissions follow IS92*a*. Note that, with the exception of the DK proposal, the FR and NL proposals bracket the others. Figure 4 shows global emissions out to 2100 for combinations where the FR and NL proposals are used for Annex I country emissions and IS92*a*, *c* and *e* emissions are used for non-Annex I countries. To ensure consistency in the population projections employed, FR-Central must be considered with IS92*a* and FR-Low with IS92*c*. As explained in Appendix 2, we combine FR-High and IS92*e* even though they use different population projections in order to maximize emissions (i.e., to minimize the effect of the proposed emissions limitation)[12].

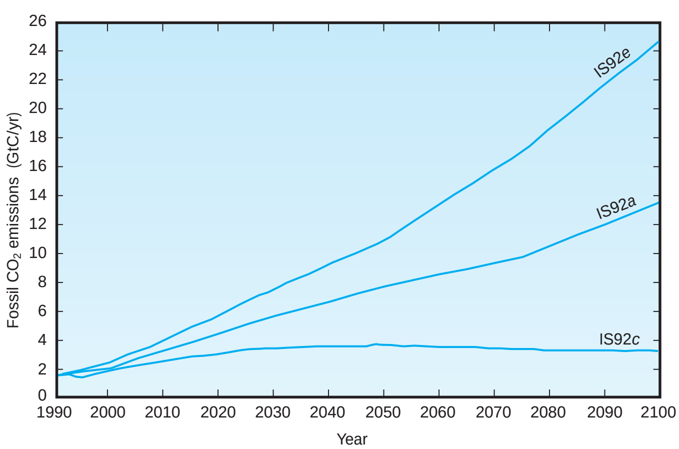

Figure 2. Fossil CO_2 emissions (GtC/yr) for non-Annex I countries under the IS92*a*, *c* and *e* emissions scenarios.

[11] It should be noted that the 1990 global fossil CO_2 emissions value given in IPCC92 is 6.2 GtC/yr. However, all CO_2 concentration calculations carried out in IPCC exercises to date have used a more recent 1990 value of 6.10 GtC/yr for the global total (see, e.g., Enting, *et al.*, 1994, Table A.3), as we do here. Further details are given in Appendix 3.

[12] Combining FR-Central and IS92*e* (which would be more consistent on the basis of the population projections employed) would lead to a limitation scenario between the FR-High and NL-1% cases, slightly closer to NL-1% than FR-High.

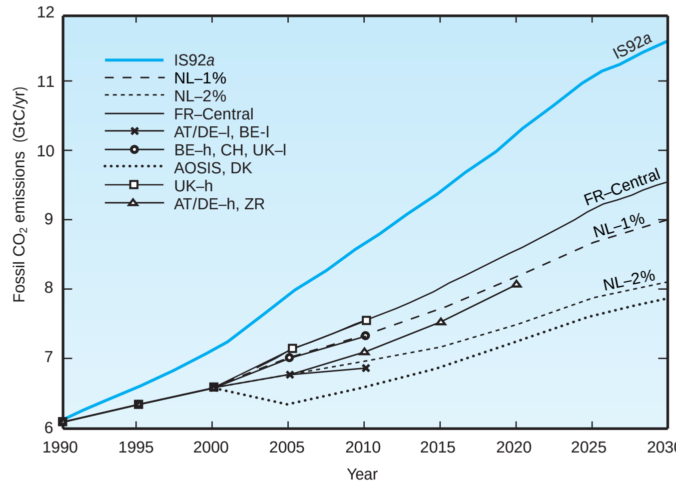

Figure 3. Global fossil CO_2 emissions where Annex I countries follow the various emissions limitation proposals (data as in Table 3) and non-Annex I countries follow IS92*a*. Global emissions under the no-limitation IS92*a* case are also given for comparison. The earlier part of the DK proposal corresponds to the AOSIS proposal, which extends only to 2005. Note that the UK-h and [BE-h, CH, UK-l] proposals, which extend only to 2010, are almost identical to FR-Central and NL-1%, respectively. Proposal 13, Philippines, (see Appendix 1) follows DK to 2005, and then declines to 5.97 GtC/yr in 2010.

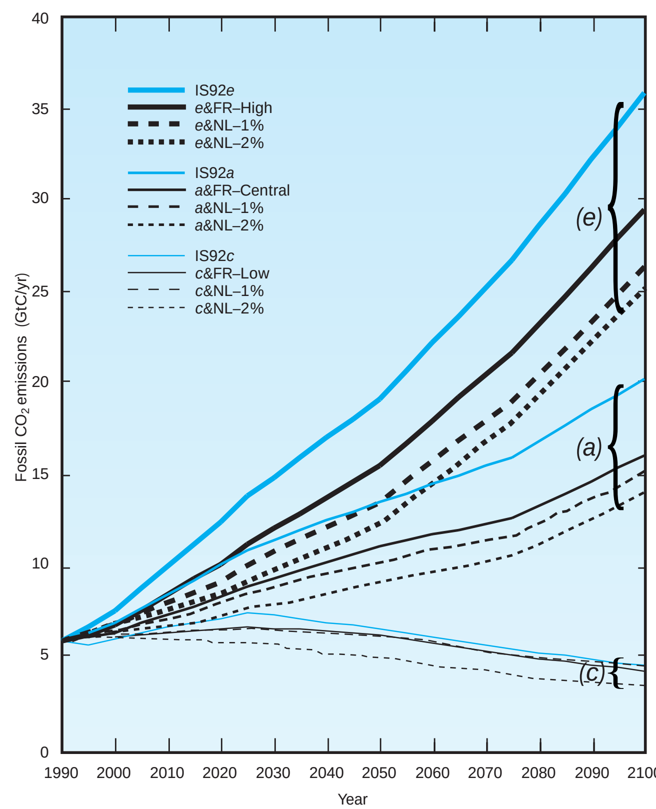

Figure 4. Global fossil CO_2 emissions (GtC/yr) under the IS92*a*, *c* and *e* scenarios, compared with their modifications where Annex I countries follow the French (FR-Low, FR-Central, FR-High) and Netherlands (NL-1%, NL-2%) emissions limitation proposals and non-Annex I countries follow the indicated IS92 case (IS92*a*, *c* or *e*).

5. CO_2 CONCENTRATION IMPLICATIONS OF THE EMISSIONS LIMITATION PROPOSALS

The global emissions scenarios in Figures 3 and 4 are interpreted in terms of future CO_2 concentrations by making use of a carbon cycle model. These calculations have been carried out using the three models employed previously in the Working Group I volume of the IPCC Second Assessment Report[13] (Schimel, *et al.*, 1996) and in TP3:

- Jain, *et al.* (1995);
- Siegenthaler and Joos (1992; see also Joos, *et al.*, 1996); and
- Wigley (1993).

All three models give similar results. Only results from the Siegenthaler and Joos model (referred to in SAR WGI and TP3 as the Bern model) are shown here. To carry out these calculations it is necessary to specify, not only the fossil CO_2 emissions that the various emissions limitation cases define, but also emissions from land-use changes. The appropriate IS92*a*, *c* or *e* land-use change emissions scenarios from IPCC92 are used here (Leggett, *et al.*, 1992).

We consider concentration effects (*a*) up to 2030, using the full set of emissions limitation proposals, and (*b*) up to 2100 using the two sets of proposals that allow such an extended analysis (i.e., the FR and NL proposals):

(*a*) *Concentration effects up to 2030.* Figure 5 shows CO_2 concentrations for the full set of proposals for Annex I countries, where the proposed emissions limitations are combined with IS92*a* emissions for non-Annex I countries (see Figure 3 for emissions). In this case, the baseline for Annex I countries, which determines the magnitude of the emissions reductions, is also IS92*a*. CO_2 concentrations for the original (no-limitation) IS92*a* emissions scenario are shown for comparison (i.e., where both Annex I and non-Annex I country emissions follow the IS92*a* scenario). The relatively wide range of emissions differences in the years up to 2030 (Figure 3) result in only small concentration differences (Figure 5). In the year 2010, the emissions limitation cases differ by less than 3 ppmv, ranging from 3.7 to 6.2 ppmv below the no-limitation (IS92*a*) case. The concentration differences are small because, even though the endpoint emissions (in 2010–2030) differ markedly between the various cases, the cumulative global emissions differences are small relative to the total cumulative emissions in any particular case.

For the four emissions limitation cases that extend to 2030, the range of concentrations is 14–25 ppmv below the IS92*a* no-limitation case. The lowest concentration is for the DK proposal (see Tables 2 and 3); this is less than 3 ppmv below the next lowest (viz. NL-2%). Thus, the full concentration range is well represented by the FR and NL proposals .

(*b*) *Concentration effects up to 2100.* Figure 6 shows concentration results out to 2100 for the emissions shown in Figure 4 (i.e., for the FR and NL emissions limitation proposals for Annex I countries, combined with IS92*a*, *c* or *e* emissions for non-Annex I countries). This figure shows the long-term effect of the different limitation proposals in reducing future CO_2 concentrations.

For the limitation cases where the baseline for the Annex I emissions reductions is IS92*a*, the concentration reductions are substantial. It should be noted, however, that, in all these cases, CO_2 concentrations in 2100 exceed double the pre-industrial level (i.e., above $2 \times 278 = 556$ ppmv), and are rising rapidly at this time (at a rate in the year 2100 of more than 3 ppmv/yr, compared with the 1980–1989 long-term rate of around 1.5 ppmv/yr — see SAR WGI, Figure 2.2); there is no indication that CO_2 concentrations are beginning to stabilize.

The situation using IS92*e* emissions as the baseline for Annex I country emissions is qualitatively the same as for IS92*a*. Since the baseline is higher, the emissions reductions under the limitation proposals are larger, so the CO_2 concentration reductions are also larger. Nevertheless, concentrations still attain high levels by 2100 (2.6–2.9 times the pre-industrial level) and are increasing very rapidly at this time (at 7–9 ppmv/yr, about five times the current rate of increase). There is no indication of any tendency towards stabilization.

When the IS92*c* scenario is used as the baseline, the situation is markedly different from the IS92*a* and *e* cases. In this case, the concentration reductions resulting from the limitation proposals are much more modest (8–33 ppmv in 2100). This is because emissions for Annex I countries under IS92*c* are quite similar to those under the limitation proposals (see Figure 1) and because emissions for non-Annex I countries under IS92*c*, the lowest of the IPCC emissions projections, never exceed 4 GtC/yr (Figure 2). With the limitation proposals, there is a clear tendency towards CO_2 concentration stabilization (eventually at around 500 ppmv if the emissions trends in 2100 were extrapolated beyond 2100). By 2100 the rate of increase in concentration in all cases where IS92*c* is used as the baseline for emissions is much less than the current rate of increase (1.5 ppmv/yr). This is also the case for the original IS92*c* global emissions scenario.

These concentration results are, of course, subject to carbon cycle modelling uncertainties, which are discussed at length in SAR WGI (Schimel, *et al.*, 1996) and in TP3. Some of these uncertainties may be quantified using the method of Wigley (1993) employed in previous IPCC work. Uncertainty estimates are calculated by varying the average value of net land-use change emissions over the 1980s[14]. Dn80s is used to initialize

[13] Hereafter referred to as SAR WGI: similarly, SAR WGII.

[14] The notation used for this quantity is Dn80s, where Dn is an abbreviation for net Deforestation.

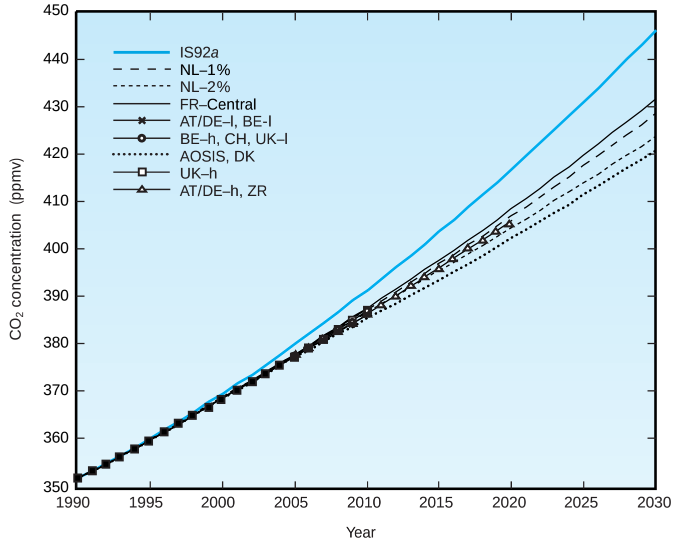

Figure 5. Global CO_2 concentrations (ppmv) calculated using the Bern model where Annex I country emissions follow the emissions limitation proposals (Table 3, Figure 3) and non-Annex I countries follow IS92*a*. Global CO_2 concentrations under the no-limitation IS92*a* case are shown for comparison. For Proposal 13, Philippines, (see Appendix 1) concentrations follow the DK proposal to 2005 and drop below this case subsequently (by 0.7 ppmv in 2010).

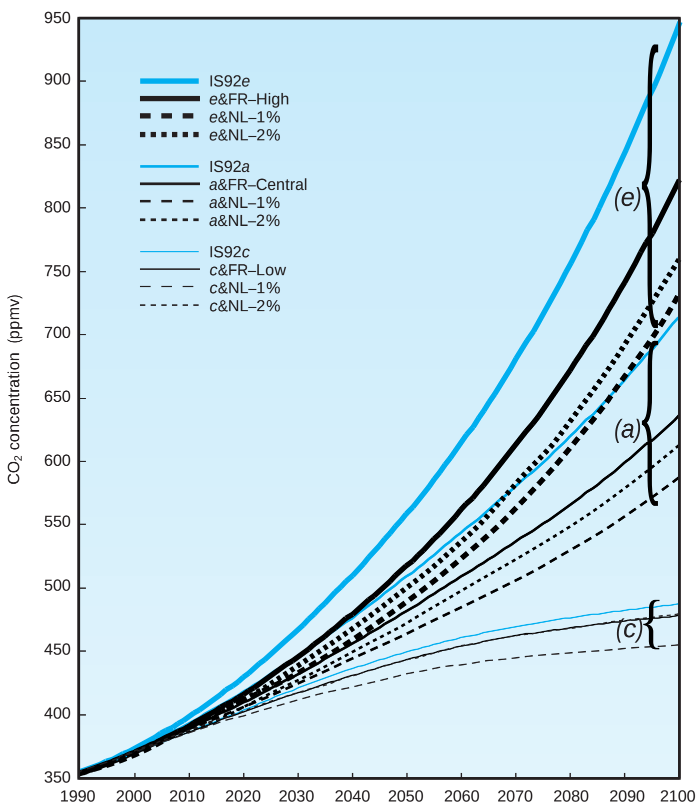

Figure 6. Global CO_2 concentrations (ppmv) calculated using the Bern model for the IS92*a*, *c* and *e* emissions scenarios compared with their modifications where Annex I country emissions follow the French (FR-Low, FR-Central, FR-High) or Netherlands (NL-1%, NL-2%) emissions limitation proposals and non-Annex I countries follow the indicated IS92 case (IS92*a*, *c* or *e*).

the carbon cycle model calculations in a way that ensures a balanced carbon budget over the 1980s (see Enting, *et al.*, 1994, and TP3 for further details of the procedure). Changing Dn80s in turn changes the magnitude of the terrestrial CO_2 fertilization§ sink used in balancing the 1980s-mean carbon budget. If the implied fertilization effect is constrained to lie within a priori defined realistic limits, this method also accounts for uncertainties in the atmosphere-to-ocean CO_2 flux (Wigley, 1993; Enting, *et al.*, 1994). A reasonable estimate of this uncertainty range may be obtained by using Dn80s = 0.4–1.8 GtC/yr (compared with the standard central value of 1.1 GtC/yr). Low values of Dn80s lead to a reduced-magnitude fertilization sink and, hence, to higher concentrations, and vice versa. In the IS92*a* (no-limitation) case, for example, the 2100 concentration uncertainty is approximately ±50 ppmv (see Table 5). As noted in SAR WGI (Schimel, *et al.*, 1996) and in TP3, there are other uncertainties associated with possible climate-related changes in the terrestrial biosphere and the ocean that could inflate this uncertainty range appreciably.

While uncertainties in concentration levels for any given case are substantial, uncertainties in the concentration reductions resulting from the various emissions limitation proposals are much less — approximately ±10 ppmv for the cases where non-Annex I country emissions follow IS92*a* (see the bracketed values in Table 5). This is because all emissions cases are subject to similar concentration uncertainties associated with the baseline upon which the limitations are imposed. The limitation proposals modify the baseline cumulative emissions by no more than 20 per cent, so the concentration uncertainty

Dn80s (GtC/yr)	*0.4*		*1.1*		*1.8*	
	Global CO_2 concentrations in 2100 (ppmv) (no emissions limitation - emissions limitation)					
No emissions limitation (IS92a)	766		712		667	
NL-1%	656	(110)	613	(99)	578	(89)
NL-2%	626	(140)	586	(126)	554	(113)
FR-Central	679	(87)	634	(78)	597	(70)

Table 5. Global CO_2 concentrations (ppmv) in the year 2100 and (in brackets) concentration reductions for the emissions limitations proposals (NL-1%, NL-2% and FR-Central) when Annex I country emissions under these proposals are combined with IS92*a* emissions for non-Annex I countries. Concentration values are mid-year values. Reductions are relative to the "no emissions limitation" (IS92*a*) case. Estimates are given for three different values of the average net land-use change emissions (GtC/yr) during the 1980s (Dn80s) in order to reflect uncertainties in modelling the carbon cycle. Lower Dn80s leads to lower CO_2 fertilization and higher concentrations. Note that the uncertainty range for IS92*a* is at least ±50 ppmv, while the uncertainty range for the concentration reductions is only around ±10 ppmv.

associated with them is only one-fifth as large as that associated with the baseline. Because of this, uncertainties in the concentration differences between emissions limitation cases are relatively small — although this may not be the case if a major change occurred in the behaviour of the carbon cycle. When expressed in terms of radiative forcing differences the uncertainties are even smaller (see Table 6). This further reduction in uncertainty occurs because of the non-linear (logarithmic) relationship between radiative forcing and CO_2 concentration (IPCC Scientific Assessment[15] — Shine, *et al.*, 1990). Since the larger concentration uncertainties occur in cases where the baseline concentrations are higher (i.e., IS92*e*) their effect on radiative forcing per unit of concentration change is less.

[15] Hereafter referred to as IPCC90.

	IS92a			*IS92c*	*IS92e*
Dn80s (GtC/yr)	*0.4*	*1.1*	*1.8*	*1.1*	*1.1*
	Change in radiative forcing between 1990 and 2100 (W m^{-2})				
No emissions limitation	4.87	4.40	3.99	2.03	6.19
	Radiative forcing reductions relative to the no emissions limitation scenarios (W m^{-2})				
NL-1%	0.98	0.94	0.90	0.10	1.38
NL-2%	1.27	1.22	1.17	0.43	1.62
FR-Low				0.12	
FR-Central	0.76	0.73	0.70		
FR-High					0.89

Table 6. Increase in radiative forcing between 1990 and 2100 (W m^{-2}) in the absence of any emissions limitation proposal (top row) and reductions due to the FR and NL emissions limitation scenarios. Results for IS92*a* are given for different values of the 1980s-mean net land-use change emissions (GtC/yr) amount (Dn80s) to illustrate the effect of carbon cycle model uncertainties. Lower Dn80s leads to lower CO_2 fertilization and higher concentrations. Concentration values for these cases are given in Table 5. Note that the radiative forcing differentials are relatively insensitive to the Dn80s value, and hence, to carbon cycle model uncertainties. To compute forcing, the standard relationship from IPCC90 (Shine, *et al.*, 1990) has been used.

6. PROPOSED EMISSIONS LIMITATIONS RELATIVE TO STABILIZATION REQUIREMENTS

Since none of the proposed emissions limitations for Annex I countries leads to CO_2 concentrations that approach stabilization when combined with IS92*a* or IS92*e* emissions for non-Annex I countries, and since greenhouse gas concentration stabilization is the ultimate objective of the FCCC, we consider in this Section what additional emissions reductions might be needed to achieve this goal. We do this by comparing the global emissions requirements for stabilization, given and discussed in SAR WGI (Schimel, *et al.*, 1996) and TP3, with emissions under the FR and NL limitation proposals.

In the cases where non-Annex I country emissions follow IS92*a* or *e*, concentrations in 2100 range between approximately 575 and 950 ppmv even when the strongest limitation case is considered. The situation is qualitatively different when Annex I country emissions are combined with IS92c emissions for non-Annex I countries (Figure 6). In these cases, by 2100, concentrations under the various emissions limitation proposals increase much more slowly than in 1990 tending towards stabilization at approximately 500 ppmv or less. These results imply that unless population growth, economic growth, technological change and other factors combine in such a way that global emissions mimic the low-emission IS92*c* scenario, substantial global emissions reductions beyond those defined by the various emissions limitation proposals would be required.

If stabilization is to be achieved, the carbon cycle itself constrains the pathway for global emissions within a relatively restricted range (for any given stabilization target) determined by the concentration pathway (or "profile§") along which stabilization is reached. The differences in emissions between the "S" and "WRE" concentration profiles[16] illustrate this range; further examples are given in Wigley, *et al.* (1996, Figure 2). When CO_2 emissions for different stabilization profiles are compared with those for the various emissions limitation cases, the difference between the carbon cycle emissions constraint and the limitation scenario tells us what additional global emissions reductions are necessary to reach a particular concentration stabilization target. Note that these calculations determine only the additional global emissions reductions that are required. How these additional reductions are apportioned either between non-Annex I and Annex I countries, or across time, depends on political and economic considerations.

[16] IPCC has illustrated the effect of concentration pathway on emissions by using two different sets of concentration profiles ("S" and "WRE"). For any given stabilization level, these profiles span a wide range of possibilities. The "S" pathways were defined in Enting, *et al.* (1994); the "S" stands for Stabilization. The "WRE" profiles were defined in Wigley, Richels and Edmonds (1996) whose initials provide the acronym. Emissions for the "S" series deviate from the central IS92*a* scenario as early as 1990, whereas emissions for the "WRE" series are constrained to follow IS92*a* out to 2000 or later depending on the stabilization level.

In Figure 7 global emissions under the FR and NL emissions limitation proposals, with non-Annex I country emissions following the IS92*a* scenario, are compared with emissions paths that would achieve stabilization at 450, 550 (approximately double the pre-industrial level — i.e., 2 × 278 = 556 ppmv) and 650 ppmv. Both the "S" and "WRE" concentration profiles are considered. The emissions results for the stabilization cases are those determined by the Bern model (Siegenthaler and Joos, 1992) and are the same as given in SAR WGI (Schimel, *et al.*, 1996) and TP3. Note that there is currently no agreement about which stabilization level might be appropriate. In SAR WGI (Schimel, *et al.*, 1996) and TP3 additional stabilization levels of 350 ppmv, 750 ppmv and 1000 ppmv are considered. The results presented here represent a middle range of possibilities, easily generalized to other cases.

For stabilization at 450 ppmv, the emissions limitation cases lie between the "S" and "WRE" pathways for the first few decades of the next century, after which they rise increasingly above the emissions for both stabilization cases (Figure 7). Additional, and eventually substantial, reductions in global emissions beyond those given by the limitation scenarios would therefore be required at some time during the early decades of the twenty-first century if a 450 ppmv stabilization target were to be chosen. Eventual stabilization at concentrations of 550 ppmv and above would permit global emissions to follow any of the proposed limitation pathways at least through the initial decades of the twenty-first century, but substantial reductions below the limitation pathways would still eventually be required. The higher the stabilization target, the longer can the proposed limitation paths be followed and still feasibly attain the target.

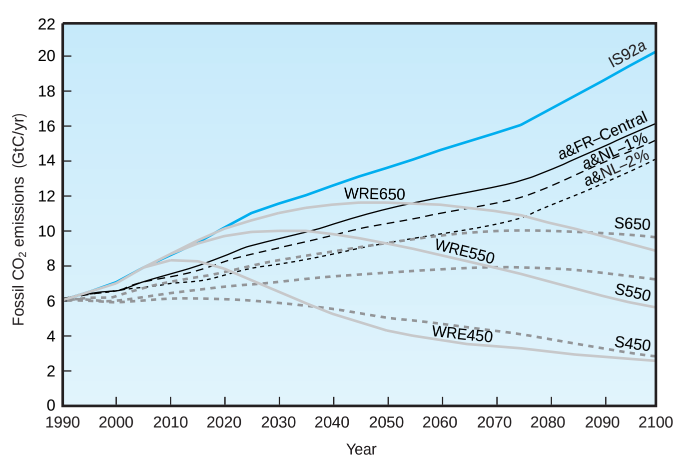

Figure 7. Global fossil CO_2 emissions (GtC/yr) for the IS92*a* scenario and modifications of it based on proposed limitations to Annex I country emissions (NL-1%, NL-2% and FR-Central) compared with emissions required to follow the S450, 550 and 650 and WRE450, 550 and 650 concentration stabilization profiles. Stabilization results calculated using the Bern model.

As a general result, the later global emissions deviate from a particular pathway that does not lead to concentration stabilization (such as IS92*a*), the larger the subsequent emissions reductions must be in order to achieve stabilization. This principle is clearly demonstrated by a comparison of the "S" and "WRE" emissions paths, noting that the latter follow IS92*a* initially, while the "S" pathways begin to deviate from IS92*a* in 1990. In the same way, since none of the emissions limitation proposals when combined with IS92*a* emissions for non-Annex I countries approaches stabilization (see Figure 6), the later global emissions deviate from these limitation pathways, the greater the future emissions reduction must be to achieve any given stabilization target. In addition, the longer a particular limitation pathway is followed, the smaller is the cumulative impact on the climate system (i.e., through the reduction in global mean temperature increase or sea level rise) — see, e.g., Wigley, *et al.* (1996, Figure 3).

These results apply specifically to the case where non-Annex I country emissions follow IS92*a*. As noted earlier, if non-Annex I country emissions were to follow IS92*c* and Annex I country emissions were to follow IS92*c* or any of the limitation proposals, then stabilization would occur at a level near 500 ppmv with little or no additional intervention. If, however, non-Annex I country emissions were to follow IS92*e*, additional global emissions reductions beyond the limitation proposals would be required earlier than in the IS92*a* case.

These results arise because concentration stabilization requires an eventual reversal of the current upward trend in CO_2 emissions, no matter which stabilization target is chosen. For the emissions limitation cases in which non-Annex I country emissions follow IS92*c*, a reversal occurs early in the twenty-first century and, by 2100, there is a clear tendency towards concentration stabilization. For emissions limitation cases where non-Annex I countries follow IS92*a* and IS92*e*, global emissions rise continuously through the twenty-first century (see Figure 4). Substantial additional emissions reductions are required to reverse the trend. There are economic, social, technological and political constraints on how emissions trends can be reversed, but a consideration of these constraints is beyond the scope of this Paper. For further information, see TP3.

The various emissions limitation proposals also have different implications for climate change, which can be broadly assessed through their effects on global mean temperature and sea level. These effects are considered in the next Section.

7. GLOBAL MEAN TEMPERATURE AND SEA LEVEL CONSEQUENCES OF THE PROPOSED EMISSIONS LIMITATIONS

To determine the consequences of the various emissions limitation proposals on global mean temperature and global mean sea level we use the models employed in SAR WGI (Kattenberg, *et al.,* 1996). Further details of these models are given in Raper, *et al.* (1996) and TP2 (Harvey, *et al.,* 1997). These calculations are subject to a number of uncertainties; the primary ones arise from (*a*) the range of emissions limitation proposals and the assumed emissions for non-Annex I countries; (*b*) uncertainties in our understanding of the physical processes involved; and (*c*) choices in how we account for the influences of gases other than CO_2:

(*a*) *Range of limitation proposals and assumed emissions for non-Annex I countries.* To gauge the range of possible effects spanned by the different limitation proposals, we consider only the most extreme case, NL-2%. For non-Annex I countries we consider three cases: CO_2 emissions following the IS92*a*, *c* and *e* scenarios. It is necessary to specify the non-Annex I country emissions because the implications of a reduction in Annex I country emissions depend on the global emissions level. The same reduction has a greater effect on radiative forcing, temperature change and sea level rise when global emissions are small compared with the case when global emissions are large[17]. In spite of this important effect, over relatively small emissions ranges (such as those spanned by the different limitations proposals at any one point in time), the temperature and sea level responses still vary approximately linearly with global emissions. It is therefore possible to generalize the results presented here by linear interpolation. The results, as noted earlier, also apply to cases where the proposed emissions limitations are expressed in CO_2-equivalent terms (see TP3);

(*b*) *Uncertainties in the physical processes.* To quantify uncertainties arising from our incomplete understanding of the relevant physical processes, we use a range of model parameter values. This is the procedure used in SAR WGI (Kattenberg, *et al.*, 1996). For global mean temperature, we carry out simulations using three values of the climate sensitivity; viz. equilibrium global mean temperature increases for a CO_2 doubling (ΔT_{2x}) of 1.5, 2.5 and 4.5°C. All other climate model parameters are as used in SAR WGI, and the simulations use the same slow-down in the thermohaline circulation and the same land/ocean differential climate sensitivity employed in that work. Uncertainties arising from parameters other than the climate sensitivity are relatively small, as demonstrated, for example, in Wigley and Raper (1993). For sea level we consider low, mid and high ice-melt parameter cases. As in SAR WGI (Warrick, *et al.,* 1996), we combine these with low, mid and high climate sensitivities to better explore the uncertainty range for sea level;

(*c*) *Influence of gases other than CO_2.* To account for the influences of other gases, we use an idealized "baseline" case for their emissions; specifically, the baseline case used in TP3. Here, the emissions of CH_4, N_2O and SO_2 are kept constant at their 1990 values, and halocarbons follow a scenario consistent with the Copenhagen version of the Montreal Protocol[§]. As in SAR WGI (Kattenberg, *et al.,* 1996), CH_4 and N_2O emissions are modified from the values given in the IS92 scenarios to ensure a balanced 1990 budget for these gases. This constant 1990 emissions case not only has the advantage of consistency with TP3, but it also avoids complications that might arise because of differences in the emissions of non-greenhouse gases between the IS92 scenarios. Furthermore, by reference to the sensitivity study results given in TP3, it is possible to estimate how the results would be affected by deviations from the constant emissions case for CH_4, N_2O and SO_2 individually.

The global mean temperature and sea level consequences of the NL-2% emissions limitation scenario are shown in Figures 8 to 10. These figures compare "no-limitation" cases, where global CO_2 emissions follow the IS92*a*, *c* and *e* scenarios, and "limitation" cases, where non-Annex I country emissions follow IS92*a*, *c* and *e* and Annex I country emissions follow NL-2%. Each figure gives projections for three values of the climate sensitivity (ΔT_{2x}=1.5, 2.5 and 4.5°C), combined with low, mid and high ice-melt estimates for the sea level results.

The influence of the NL-2% emissions limitation scenario in reducing global mean temperature and sea level depends on the emissions case used as the baseline for Annex I emissions (IS92*a*, *c*, or *e*), total global emissions (i.e., the emissions assumed for non-Annex I countries), and on the climate sensitivity and ice-melt parameters. Reductions are greater for cases where the Annex I country emissions baseline is higher, since these have larger emissions reductions for any given limitation proposal; and reductions are greater for larger values of the climate sensitivity and/or ice melt. Temperature reductions for the NL-2% case in the year 2100 (low to high climate sensitivity results) are 0.34–0.68°C for IS92*a*; 0.11–0.23°C for IS92*c*; and 0.44–0.91°C for IS92*e*. The corresponding sea level reductions are 4.5–11.5 cm for IS92*a*; 1.6–4.6 cm for IS92*c*; and 6.2–15.0 cm for IS92*e*.

Because of the close empirical relationships between CO_2 emissions in a particular year, cumulative CO_2 emissions to that year, CO_2 concentration and radiative forcing in that year, and

[17] This effect arises mainly because of the non-linear (logarithmic) dependence of radiative forcing on CO_2 concentration. For CO_2, the concentration reduction caused by a given emissions reduction is actually less for lower global emissions; but this effect is more than offset by the non-linear forcing–concentration relationship.

the corresponding temperature and sea level values (for any given set of model parameters) in the cases considered here, it is possible to generalize the present results to other cases not considered specifically. The above-mentioned relationships have the characteristic that the temperature and sea level changes to any given year are almost linearly related to the CO_2 emissions level in that year. This is shown for the year 2020 in Figure 11. Similar results can be derived for any year; the fit to a linear relationship becomes slightly less good as the date is moved further into the future. To obtain results for 2020 for an emissions limitation case not considered here, the appropriate 2020 emissions value can simply be entered into Figure 11, a climate sensitivity value selected, and an estimate of temperature or sea level change read off using the straight line fitted to the data points. Because all changes are nearly linear in time, it is possible to generalize 2020 results to other years using Figures 8 to 10. These methods of interpolation should, however, be used cautiously; they should only be applied to situations where emissions vary smoothly with time, comparable to the cases considered here.

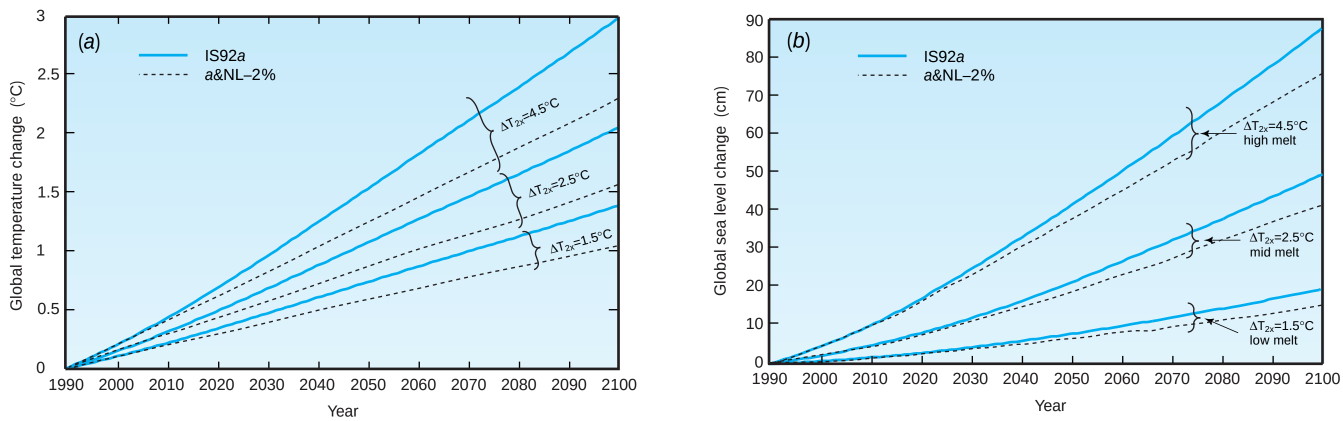

Figure 8. (*a*) Effect of the NL-2% emissions limitation proposal on global mean temperature (°C) for different values of the climate sensitivity (ΔT_{2x}). We consider the "no-limitation" case, where Annex I and non-Annex I country CO_2 emissions follow the IS92*a* scenario, and "limitation" case, where non-Annex I country emissions follow IS92*a* and Annex I emissions follow NL-2%. (*b*) As for (*a*), but for global mean sea level (cm). The 1.5, 2.5 and 4.5°C climate sensitivities are combined with low, mid and high ice-melt parameters, respectively.

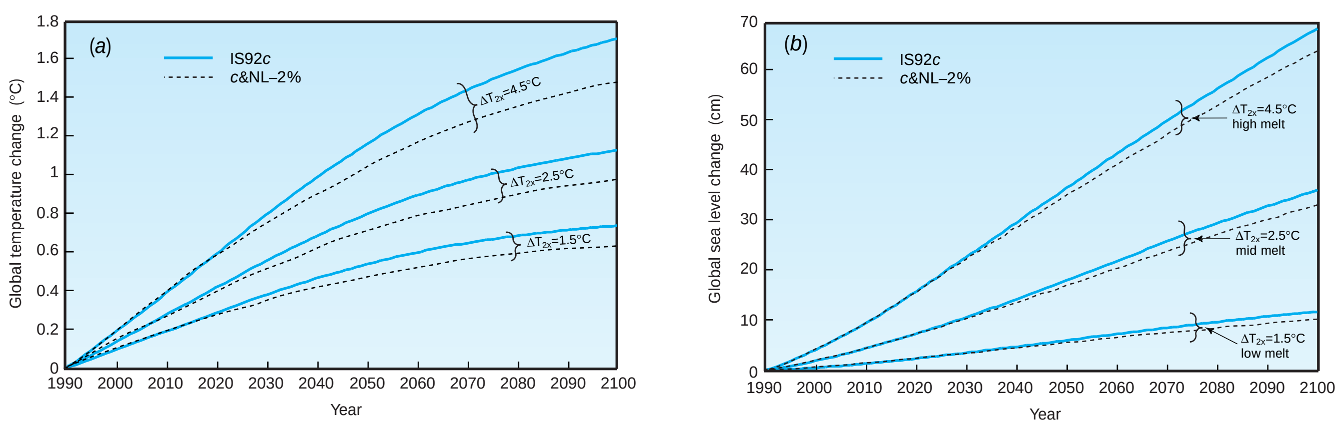

Figure 9. (*a*) Effect of the NL-2% emissions limitation proposal on global mean temperature (°C) for different values of the climate sensitivity (ΔT_{2x}). We consider the "no-limitation" case, where Annex I and non-Annex I country CO_2 emissions follow the IS92*c* scenario, and "limitation" case, where non-Annex I country emissions follow IS92*c* and Annex I emissions follow NL-2%. (*b*) As for (*a*), but for global mean sea level (cm). The 1.5, 2.5 and 4.5°C climate sensitivities are combined with low, mid and high ice-melt parameters, respectively.

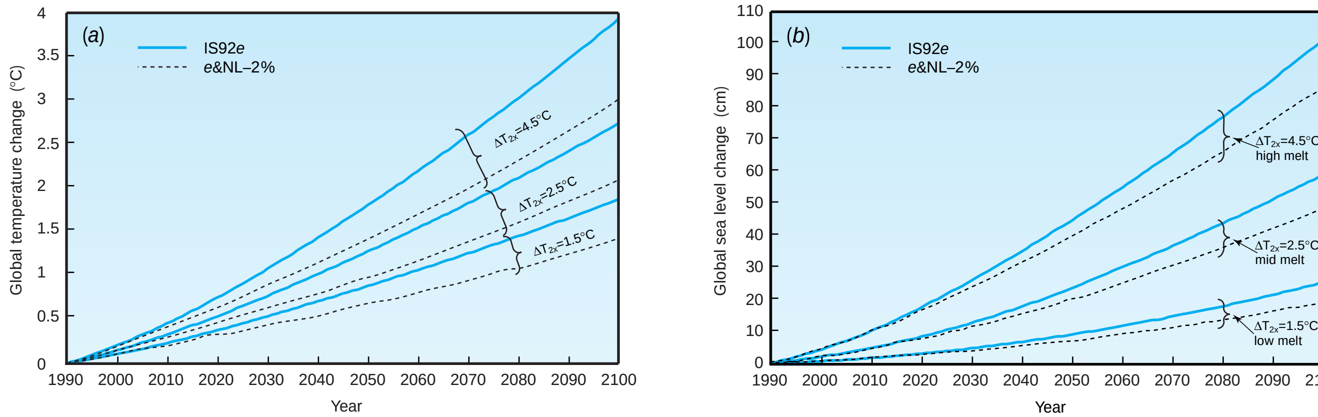

Figure 10. (*a*) Effect of the NL-2% emissions limitation proposal on global mean temperature (°C) for different values of the climate sensitivity (ΔT_{2x}). We consider the "no-limitation" case, where Annex I and non-Annex I country CO_2 emissions follow the IS92*e* scenario, and "limitation" case, where non-Annex I country emissions follow IS92*e* and Annex I emissions follow NL-2%. (*b*) As for (*a*), but for global mean sea level (cm). The 1.5, 2.5 and 4.5°C climate sensitivities are combined with low, mid and high ice-melt parameters, respectively.

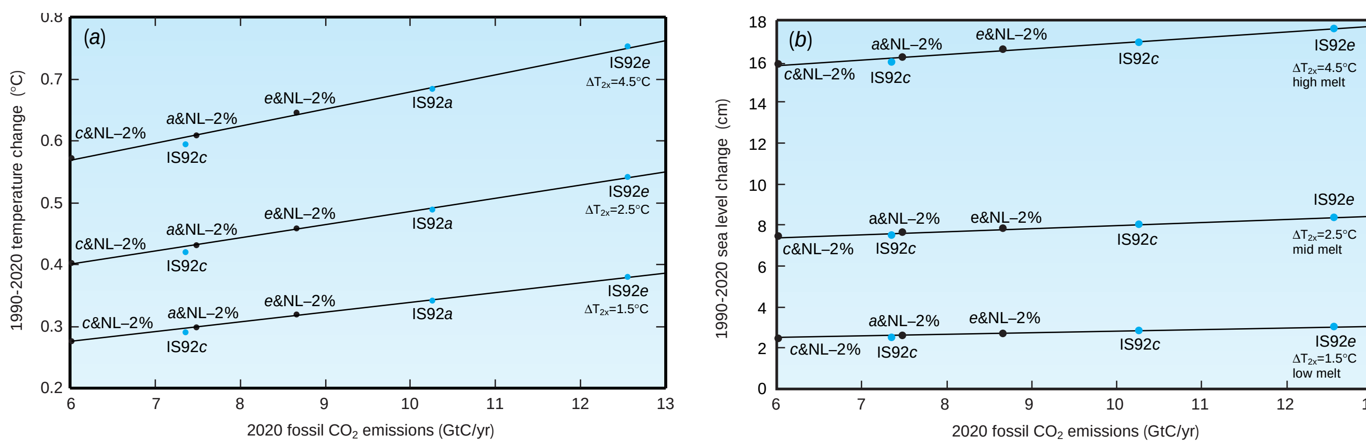

Figure 11. (*a*) Relationship between global fossil CO_2 emissions in the year 2020 (GtC/yr) and global mean temperature change (°C) over 1990–2020. Results are given for different values of the climate sensitivity (ΔT_{2x}). The dots represent individual case values as given in Figures 8–10, while the straight lines give the least-squares linear fit between these data points. The straight lines may be used to interpolate results for 2020 emissions levels other than those specifically analysed in this Paper. (*b*) As for (*a*) but for global mean sea level change (cm). The 1.5, 2.5 and 4.5°C climate sensitivities are combined with low, mid and high ice-melt parameters, respectively.

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NOTE: The official documents from the United Nations FCCC quoted in this Technical Paper can be found in the FCCC Web site (http://www.unfccc.de).

Appendix 1

RECENT EMISSIONS LIMITATION PROPOSALS

As noted in the main text, a new set of emissions limitation proposals and withdrawals was put forward by the AGBM in the negotiating text (FCCC/AGBM/1997/3/Add.1 dated 22 April 1997) after the initial draft of this Technical Paper had been prepared. This negotiating text did not include the names of Parties making proposals; however we have added them here for clarity (Table A1). With one exception, where these proposals are expressed in specific quantitative terms, they all lie within the range of possibilities already considered. Currently, no proposal has been adopted, so any set of analyses of the implications of proposed emissions limitations can only be considered as a guide to the range of possible implications. We have shown in Section 7 how new situations may easily be quantified using the results already presented. Our judgment is, therefore, that no new calculations using the newer proposals are necessary, except for Proposal 13 (Philippines) (which, strictly speaking, is also unnecessary since its implications can easily be derived by extrapolation from the earlier presented material). It should be noted that some of these proposals relate to principles for constructing emissions limitation proposals rather than providing specific quantitative suggestions. In some of these cases, it is necessary to indicate unspecified targets and dates: we do this here using P_1, P_2, etc. for percentage changes for Annex I countries and [2000 + *x*], [2000 + *y*] and [2000 + *z*] for dates, where *x*, *y* and *z* are numbers of years. In the original document (FCCC/AGBM/1997/3/Add.1, dated 22 April 1997) many of the suggestions provide much more detail than given here.

Proposals	*Parties making proposal*	*Parties receiving commitments*	*Emissions limitation proposals (FCCC/AGBM/1997/3/Add.1)*
1	Trinidad & Tobago, on behalf of the AOSIS	Annex I	Reduce CO_2 emissions by 20 per cent by 2005 relative to 1990 emissions and adopt specific targets and timetables for other ghg.
2	Australia	Annex A[18]	The target for ghg emissions for individual countries in the year 2010 should lie between -30 and +40 per cent of the 1990 level.
3	Netherlands, on behalf of the EU and its member States	Annex X[19]	Achieve significant reductions in ghg emissions below 1990 level within specified time-frames after 2000. Reduce emissions of CO_2, CH_4 and N_2O together (weighted total, using GWP with a 100 year time horizon), by *at least 7.5 per cent*[20] by 2005 and by 15 per cent by 2010 (reference year 1990). HFC, PFC AND SF_6 should be added no later than 2000 to the basket of gases for the above reduction objectives.

[18] Annex A lists the Parties currently listed in Annex I to the Convention but it is opened for other Parties, such as those joining the OECD.

[19] Annex X includes the Parties currently listed in Annex I to the Convention plus Croatia, Czech Republic, Liechtenstein, Mexico, Republic of Korea, Slovak Republic and Slovenia. Additions of developed countries or countries with economies in transition could be made. Note that Czechoslovakia is listed in Annex I to the Convention as one country.

[20] This reduction target of "*at least 7.5 per cent*" was agreed in the Council Conclusions of 19 June 1997.

Table A1. Emissions limitations proposals put forward after the initial draft of this Technical Paper (FCCC/AGBM/1997/3/Add.1, dated 22 April 1997).

Table A1. *Continued*

Proposals	*Parties making proposal*	*Parties receiving commitments*	*Emissions limitation proposals (FCCC/AGBM/1997/3/Add.1)*
4	Iceland and Norway	Annex I	(*a*) Net emissions of ghg over [2000 + x_1] to [2000 + x_2] should be P_1 per cent lower than the level in year 1990 + z_1 (or the average over some equivalent period); (*b*) Net emissions of ghg over the later period [2000 + y_1] to [2000 + y_2] should be P_2 per cent lower than the level in year 1990 + z_2 (or the average over some equivalent period). "Norway has, under the conditions of differentiation, comprehensiveness, flexibility and harmonization, proposed a common emission target of 10-15 per cent reduction of ghg emissions for Annex I Parties by 2010"[21].
5	Japan	Annex I	Each Party may select one of the two specifications: (*a*) Per capita CO_2 emissions over [2000 + x] to [2000 + x + [5]] should be at or below some specified level; (*b*) CO_2 emissions over [2000 + x] to [2000 + x + [5]] should be at or below P per cent below the 1990 level.
6	Russian Federation	Annex A plus other developed countries	Maintain an average ghg emissions level over 2000–2010 at 1990 levels or at the level of some other agreed base year. Emissions should be reduced after 2010.
7	Switzerland	Annex I	As a first step a 10 per cent reduction of the total ghg emissions by 2010 relative to 1990.
8	New Zealand	Annex [*][22]	For n intervals each of y years, beginning in [2000 + x], ghg emission limitation commitments shall be established.
9	Peru	Annex I	(*a*) Return ghg emissions to 1990 levels by 2000; (*b*) Reduce CO_2 emissions by 2005 by 15 per cent relative to 1990, and establish realistic 2005 targets for other ghg; and (*c*) Reduce ghg emissions by an additional 15–20 per cent of the 1990 levels by 2010. (This proposal also includes emissions reduction penalty clauses for Parties that fail to meet targets).
10	USA	Annex A[23] and Annex B[24]	(*a*) Each Annex A and B Party would be allocated a net ghg multiyear target referred to as an emissions budget; (*b*) The emissions budget of each Annex A Party would equal a fixed percentage of its 1990 emission times the number of years in the budget period; (*c*) The emissions budget of each Annex B Party would be proposed by that Party and agreed in a consultative process with existing Annex A and B Parties; (*d*) The emissions budget can be augmented through emissions trading, joint implementation for credit and banking.

[21] Norwegian statement in AGBM's sixth session (Bonn, 3-7 March 1997).

[22] Annex [*] shall be the list of Annex I Parties to the Convention and other Parties that may assume legally binding emission limitation commitments under the Protocol.

[23] For the USA proposal, Annex A would include those Parties listed in Annex I to the Convention, plus those that join subsequently pursuant to Article 2.

[24] Annex B would include those Parties not included in Annex A that indicate before adoption of the Protocol that they want to be included in this Annex, plus those that join subsequently pursuant to Article 2.

Table A1. *Continued*

Proposals	*Parties making proposal*	*Parties receiving commitments*	*Emissions limitation proposals (FCCC/AGBM/1997/3/Add.1)*
11	Democratic Republic of Congo	Annex I	Parties that return ghg emissions to 1990 level by 2000 would reduce ghg emissions by 10 per cent relative to 1990 by 2005; reduce ghg emissions by 15 per cent relative to 1990 by 2010; and reduce ghg emissions by 20 per cent relative to 1990 by 2020. (This proposal also includes emissions reduction penalty clauses for Parties that fail to meet targets).
12	United Republic of Tanzania, on behalf of the Group of 77 and China	Annex I	(*a*) Return ghg emissions to 1990 levels by 2000; (*b*) Reduce ghg emissions by P_1 per cent relative to 1990 by 2005; and (*c*) Further reduce ghg emissions by P_2 per cent relative to 1990 by 2010.
13	Philippines	Annex I	(*a*) Return ghg emissions to 1990 levels by 2000; (*b*) Reduce ghg emissions by 20 per cent relative to 1990 by 2005; and (*c*) Further reduce ghg emissions by 20 per cent relative to 1990 by 2010. (This proposal also includes emissions reduction penalty clauses for Parties that fail to meet targets)
14	A group of Associated Countries to the EU (Bulgaria, Estonia, Hungary, Latvia, Poland, Romania, Slovakia and Slovenia)	Annex XX[25]	(*a*) Reduce emissions of CO_2, CH_4 and N_2O together (weighted total, using GWP with a 100 year time horizon) to 1990 level, or lower by 2005 (reduction percentage is announced upon ratification); (*b*) Beyond 2005, control and/or reduce emissions of CO_2, CH_4 and N_2O.
15	Czech Republic	Annex X	Reduce emissions of CO_2, CH_4 and N_2O (aggregated, using GWP with 100 year time horizon) by 5 per cent relative to 1990 by 2005 and by 15 per cent relative to 1990 by 2010. Reductions before 2000 be used to implement the target.
16	Canada	Not specified	Baseline ghg emissions levels should be established as the average over some agreed set of years. Targets should be specified (presumably relative to the baseline) in terms of averages over agreed future periods.

[25] Annex XX is a variation of Annex X from the EU proposal.

Note that Brazil has put forward a target of a 30 per cent reduction of CO_2, CH_4 and N_2O by 2020 subsequent to this negotiating text. The original proposal is contained in FCCC/AGBM/1997/MISC.1/Add.3 and was included as Alternative I (para. 11) in FCCC/AGBM/1997/INF.1.

Appendix 2

QUANTIFICATION OF FRENCH (FR) AND NETHERLANDS (NL) EMISSIONS LIMITATION PROPOSALS

The objective of this Appendix is to quantify the French (FR) and Netherlands (NL) emissions limitation proposals in order to put them into a perspective relative to the proposals put forward by other countries (see Table 3 in the main text) and the IPCC IS92 scenarios. We begin by considering the proposals themselves in terms of Annex I country emissions. We then extend these results to the global scale by incorporating non-Annex I country emissions. As noted in the main text, non-Annex I country emissions are based on the assumption of no emissions limitations for these countries. Note also that, although the proposals refer to reductions of greenhouse gas emissions, we take these to apply to fossil CO_2 emissions alone.

The FR and NL proposals provide a useful comparison because they are based on quite different emissions criteria, per capita emissions in the former and absolute emissions in the latter. The use of per capita emissions introduces an additional element of uncertainty, future population, which makes the calculation of absolute emissions quite complex. While per capita emissions can provide a useful unifying concept for comparisons between different countries (and between Annex I and non-Annex I countries in particular), the complexity of the calculations given below would make any emissions limitations proposal worded in this way more difficult to implement.

Annex I Country Emissions

For the NL proposal, delineation of future fossil CO_2 emissions for Annex I countries is straightforward. For these countries, IPCC92 (Leggett, *et al.*, 1992) and Pepper, *et al.* (1992) may be used to give a value of 4.59 GtC/yr for fossil CO_2 emissions in 1990 (further information is given in Appendix 3). We assume (see main text) that emissions of Annex I countries remain at 1990 levels to 2000. Therefore, the suggested decline by 1–2 per cent (compound) per year (main text, Table 1) must be assumed to begin in 2000 (as given in Table 2 in the main text). We consider two separate cases: a decline from 2000 at 1 per cent compound per year (NL-1%) and a decline from 2000 at 2 per cent compound per year (NL-2%).

The FR proposal is more complicated. Again, our analysis of this proposal includes the assumption of constant 1990-level Annex I country emissions over 1990–2000. Over 2000–2010, emissions changes are specified as a drop of 7–10 per cent in emissions per capita. To calculate the implied absolute emissions values, we need to know the projected value of emissions per capita in the year 2000. IPCC documents may be used to estimate this value, but as a range of possibilities dependent on the scenario for future population (see Table 4 in the main text).

For the IS92 scenarios, three population projections were employed, the UN Medium-Low case (used in IS92*c* and *d*), a central World Bank case (used in IS92*a*, *b* and *e*), and the UN Medium-High case (used in IS92*f*). Estimated population values for 2000 in these projections for Annex I countries are 1.286 bn, 1.313 bn and 1.354 bn, linearly interpolated from Table 4. These values, together with a total emissions value of 4.59 GtC/yr, give per capita annual emissions of 3.57 tC/yr, 3.50 tC/yr and 3.39 tC/yr, respectively in 2000, compared with a 1990 value of 3.63 tC/yr. Since the range is relatively small, and the 2000 value is, in any event, uncertain, we take the average of the three values (3.485 tC/yr if the figures are not rounded) as a single, representative value for annual per capita emissions in 2000 (some 4 per cent below the 1990 level).

Applying the specified 7–10 per cent reduction in per capita emissions over 2000–2010 to this value for the year 2000 gives an annual emissions per capita range in the year 2010 of 3.14–3.24 tC/yr. To convert this range to actual emissions we multiply by the population value. In doing so we must again account for uncertainties in population growth: the IPCC range for 2010 population linearly interpolated from Table 4 is 1.307–1.444 bn for the UN scenarios and 1.363 bn for the World Bank scenario. The extreme-high emissions value for 2010 (high population, high per capita emissions) is, therefore, 4.68 GtC/yr. The extreme-low value (low population, low per capita emissions) is 4.10 GtC/yr. Central values range from 4.27 GtC/yr (mid population, low per capita emissions) to 4.41 GtC/yr (mid population, high per capita emissions), with a mean of 4.34 GtC/yr. This set of 2010 emissions values is illustrated in Figure B1. Numerical details are given in Table B1.

For 2100, the FR proposal gives an absolute range of emissions per capita values for Annex I countries of 1.6–2.2 tC/yr. To convert these to total emissions, we must continue to account for population growth uncertainties, as specified by IPCC and given in Table 4 of the main text. To give a high range of emissions values in 2100, we use the high emissions per capita value (2.2 tC/yr); for low, mid and high population levels this gives 1.85, 3.12 and 4.87 GtC/yr (see Table B1). Similarly, a low range, using 1.6 tC/yr per capita emissions, is 1.34, 2.27 and 3.54 GtC/yr (see Table B1).

The complete Annex I emissions limitation scenarios are obtained by combining the set of emissions values in 2010 with those for 2100, which we do simply by assuming a linear

	2010		*2100*	
	Per capita emissions (tC/yr)			
	3.14 (10% below 2000)	*3.24 (7% below 2000)*	*1.6*	*2.2*
Population projection	*Fossil CO_2 emissions for Annex I countries under the FR proposal (GtC/yr)*			
low	4.10 (FR-low)	4.24	1.34 (FR-low)	1.85
mid	4.27 (FR-mid)	4.41 (FR-mid)	2.27 (FR-mid)	3.12 (FR-mid)
high	4.53	4.68 (F-high)	3.54	4.87 (FR-high)

Table B1. Fossil CO_2 emissions (GtC/yr) for Annex I countries under the French (FR) emissions limitation proposal. For population projections, low, mid and high refer to the UN Medium-Low, World Bank and UN Medium-High projections used in IPCC92 (Leggett, *et al.*, 1992) (see Table 4 of main text). 1990 and 2000 emissions are taken as 4.59 GtC/yr (see text). Subheadings under the 2010 column are per capita emissions and the percentage changes in per capita emissions from the 2000 value (i.e., from 3.485 tC/yr) used to derive them. Subheadings under the 2100 column are absolute annual per capita emissions values. The emissions values used to define extreme-low, central, and extreme-high cases for further analysis are indicated in the Table by the letters FR-low, FR-mid and FR-high respectively. For the central case used in the main text, the emissions values used are the averages of the indicated mid population projection values, viz. 4.34 GtC/yr in 2010 and 2.69 GtC/yr in 2100.

Abbreviation	*Population*	*2000–2010 decline in per capita emission*	*2100 per capita emission*	*2010–2100 change (GtC/yr)*
FR-High	high	low	high	4.68–4.87
FR-high (LOW)	high	low	low	4.68–3.54
FR-mid (HIGH)	mid	low	high	4.41–3.12
FR-Central	mid	mean[1]	mean[2]	4.34–2.69
FR-mid (LOW)	mid	high	low	4.27–2.27
FR-low (HIGH)	low	high	high	4.10–1.85
FR-Low	low	high	low	4.10–1.34

[1] The 2010 value is the average of low and high 2000–2010 per capita emissions decline values for the mid population case (i.e., (4.27 + 4.41)/2).

[2] The 2100 value is the average of low and high 2100 per capita emissions values for the mid population case (i.e., (2.27 + 3.12)/2).

Table B2. Fossil CO_2 emissions changes (GtC/yr) for Annex I countries over 2010–2100 based on the French (FR) emissions limitation proposal, together with the assumptions on which they are based. The "FR-Central" case is the average of the FR-mid (HIGH) and FR-mid (LOW) cases.

change with time over the 90-year interval. There are other ways in which one could interpolate between 2010 and 2100 (e.g., linearly interpolating emissions per capita rather than total emissions). However, since the aim here is to provide simple limitation scenarios that are consistent with the original proposal, the choice of interpolation method is unimportant. There are still a number of ways in which the various results may be combined; the full range of possibilities is spanned by the combinations listed in Table B2, and illustrated in Figure B1. For the calculations in the main text we use only the FR-Low, FR-Central and FR-High cases.

To summarize, five proposed emissions limitation scenarios for Annex I countries have been devised to span the range of possibilities consistent with the FR and NL proposals. These are designated FR-Low, FR-Central and FR-High (low, central and high cases based on the French proposal) and NL-1% and NL-2% (1 per cent per year and 2 per cent per year compound emissions reductions from 2000, in accordance with the NL proposal); see Figure B2.

Global Emissions

To determine global emissions, we combine these cases for Annex I country emissions with non-Annex I country emissions given by the IS92 emissions scenarios (see Figure 2 in the main text)[26]. It should be noted that the three FR Annex I cases (FR-Low, FR-Central and FR-High) correspond to low, mid and

[26] Note that these scenarios do not include emissions from combustion of bunker fuels. The global emissions value we use in 1990 does include the bunker fuel source. In 1990, this amounted to about 0.1 GtC/yr.

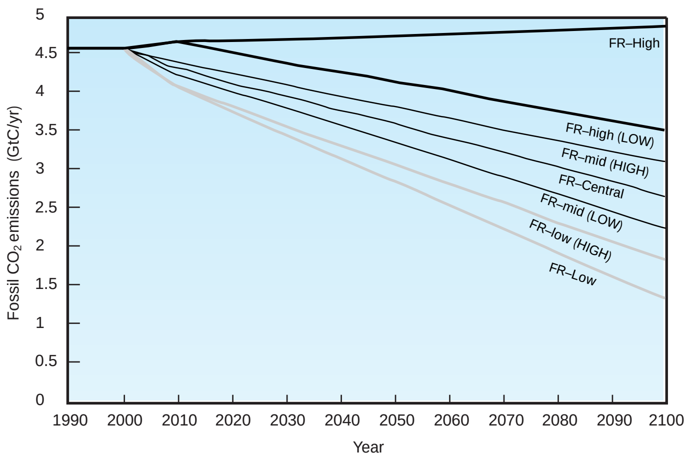


Figure B1. Fossil CO_2 emissions (GtC/yr) for Annex I countries under the French (FR) emissions limitation proposal. The words high, mid and low refer to the UN Medium-Low, World Bank and UN Medium-High population projections used, while the appended designators "HIGH", "LOW" or no designator refer to the use of high, low or mid values of per capita emissions. Changes over 2000–2010 correspond to 7–10 per cent reductions in per capita emissions accounting for uncertainties in future populations. Values in 2100 correspond to per capita emissions of 1.6 tC/yr or 2.2 tC/yr again accounting for population projection uncertainties.

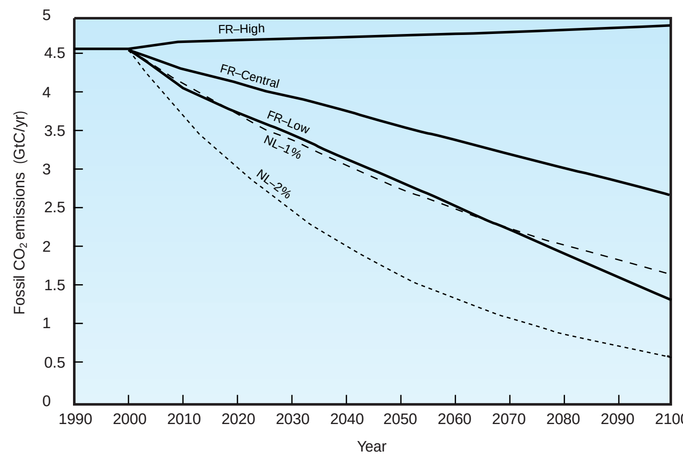
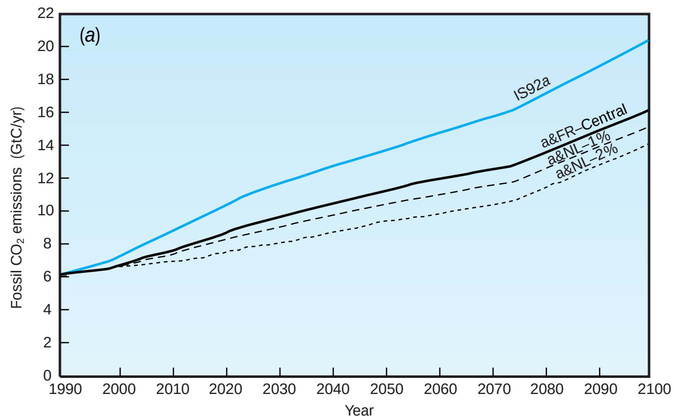


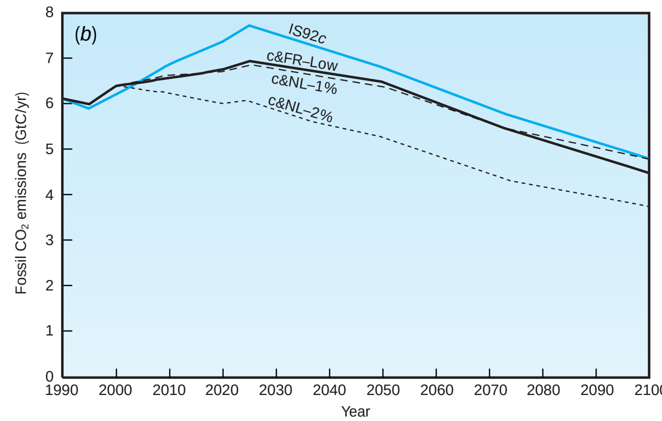
Figure B2. Fossil CO_2 emissions (GtC/yr) for Annex I countries under the French (FR) and Netherlands (NL) emissions limitation proposals. FR-High, FR-Central and FR-Low are as shown in Figure B1. NL-1% and NL-2% correspond to 1 per cent and 2 per cent per year compound emissions reductions from the 2000 level.

high population estimates. Thus, when used in conjunction with emissions for non-Annex I countries under the IS92 scenarios, only scenarios with the same population assumptions should be considered together. In the calculations in the main text, we consider only the IS92*a*, *c* and *e* scenarios for non-Annex I countries, which span the full range of emissions possibilities considered by IPCC. The only fully consistent combinations involving the FR emissions limitation proposals for Annex I countries and IS92*a*, *c* or *e* emissions for non-Annex I countries are therefore FR-Low with IS92*c*, FR-Central with IS92*a*, and FR-Central with IS92*e*.

The high population scenario is used only in IS92*f*, which, because of other assumptions made in developing this scenario (see IPCC92 — Leggett, *et al.*, 1992) has lower emissions than the mid-population-based IS92*e* case. Since we need here to span the full range of possibilities, we combine the FR-High and IS92*e* cases rather than FR-Central and IS92*e*. This maximizes non-Annex I country emissions in the absence of any limitations, while minimizing the reduction in emissions by Annex I countries. This, in turn, leads to the highest possible total for global emissions under any proposed emissions limitation scenario and, hence, the highest projected CO_2 concentration values.

For the NL emissions limitation proposals, the Annex I country emissions cases (NL-1% and NL-2%) are independent of and may, therefore, be combined with non-Annex I country emissions for each of IS92*a*, *c* and *e*. The full set of global emissions scenarios is therefore (non-Annex I case first): IS92*a* with FR-Central, NL-1% and NL-2% (Figure B3*a*); IS92*c* with FR-Low, NL-1% and NL-2% (Figure B3*b*); and IS92*e* with FR-High, NL-1% and NL-2% (Figure B3*c*). In the main text, these are illustrated together in Figure 4. Here we give the *a*, *c* and *e* results separately for greater clarity.





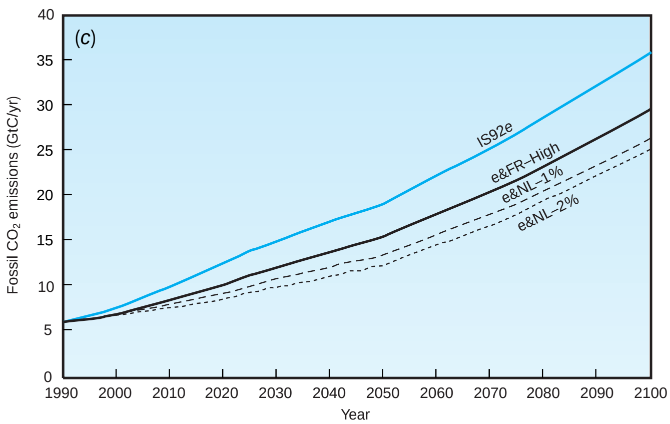


Figure B3. (*a*) Global fossil CO_2 emissions (GtC/yr) for the IS92*a* scenario compared with emissions where Annex I countries follow emissions limitation proposals NL-1%, NL-2% or FR-Central and non-Annex I countries follow IS92*a*. (*b*) Global fossil CO_2 emissions (GtC/yr) for the IS92*c* scenario compared with emissions where Annex I countries follow emissions limitation proposals NL-1%, NL-2% or FR-Low and non-Annex I countries follow IS92*c*. (*c*) Global fossil CO_2 emissions (GtC/yr) for the IS92*e* scenario compared with emissions where Annex I countries follow emissions limitation proposals NL-1%, NL-2% or FR-High and non-Annex I countries follow IS92*e*.

Appendix 3

EFFECT OF POSSIBLE ERRORS AND UNCERTAINTIES IN 1990 ANNEX I COUNTRY EMISSIONS

The emissions values used in this Paper, and their breakdown into Annex I and non-Annex I country emissions, are based primarily on information given in or prepared for the IPCC92 (Leggett, *et al.*, 1992; Pepper, *et al.*, 1992). In this Appendix we assess how sensitive the results are to the precise emissions values used in the main text. In particular, we consider the effect of uncertainties in the baseline value for Annex I country emissions, which, here, is the 1990 level for these emissions. We begin by considering the global emissions level in 1990.

For the IS92*a* scenario, the global CO_2 emissions value for 1990 given in the IPCC92 (Leggett, *et al.*, 1992, Table A3.6) is 7.4 GtC/yr. In Table A3.11 of that report, this is broken down into 6.0 GtC/yr from energy, 1.3 GtC/yr from deforestation (land-use changes), and 0.2 GtC/yr from cement production. The inconsistency here, of 0.1 GtC/yr, is a rounding error. Further details are given in Pepper, *et al.* (1992, Table 3.6.1); here, the cement production contribution is 0.15 GtC/yr. It has been noted previously (Enting, *et al.*, 1994, pp. 69, 70) that these values are insufficiently precise for carbon cycle model calculations, that rounding errors cannot be admitted into any credible analyses, and that the IPCC92 (Leggett, *et al.*, 1992) and Pepper, *et al.* (1992) emissions values in 1990 do not agree with more recent estimates. Accordingly, in IPCC work subsequent to IPCC92 the 1990 emissions value used has been 6.10 GtC/yr for emissions from energy and cement production (from Marland and Boden, 1991; but consistent with the later analysis of Marland, *et al.*, 1994 — for information, the most recently determined value is 6.11 GtC/yr). This global total includes emissions from all sources: fossil fuels including bunker fuels (fuels used for international travel) and gas flaring; cement production; and non-fuel CO_2 production.

For the breakdown into Annex I and non-Annex I countries, we rely primarily — as in TP1 (Acosta Moreno, *et al.*, 1996, Table A3, p. 78) — on IPCC92 (Leggett, *et al.*, 1992) and Pepper, *et al.* (1992). IPCC92 Table A3.7, gives 4.5 GtC/yr for the sum of OECD, USSR and Eastern Europe emissions. Although not clearly stated, this is the energy component only (as can be ascertained from Pepper, *et al.*, 1992, Tables 3.1.16–21). The cement production term adds an additional 0.09 GtC/yr (Pepper, *et al.*, Table 3.6.1). The total is therefore 4.59 GtC/yr, the main value used in this Paper. Although it is not stated specifically in IPCC92 (Leggett, *et al.*, 1992) or Pepper, *et al.* (1992), it is likely that this value does not include emissions from combustion of bunker fuels[27]. There is good reason to believe that this value is too high, partly because the IPCC92 analyses are now out of date, and partly because the above country grouping is not identical with the grouping that defines Annex I countries. In particular, the former USSR group contains a number of countries that are not in Annex I.

More recent work, noted in SAR WGII (Nakicenovic, *et al.*, 1996; Kashiwagi, *et al.*, 1996), also suggests that the value 4.59 GtC/yr may be too high. This report uses information from di Primio (1993) and Marland, *et al.* (1994), which is probably of higher quality than that used by IPCC92. Data in Marland, *et al.* (1994) indicate that a more correct value is around 4.0 GtC/yr. Since we are only concerned with estimating the sensitivity of results presented in the main text to this 1990 reference number, we do not need to know it precisely. We therefore carry out a set of analyses using 4.09 GtC/yr for 1990 Annex I country emissions, 0.5 GtC/yr below the value used for our primary calculations. How sensitive are the concentration projections given elsewhere in this report to the assumed value of Annex I country emissions in 1990? To answer this question, we need to determine how both components of future global emissions, Annex I emissions and the residual (non-Annex I plus bunker fuels[28]) emissions, would be influenced by a change in the 1990 “reference” emissions value for Annex I countries. To be specific, we consider the NL-1% and NL-2% emissions limitation proposals.

For Annex I countries, the recalculated emissions are lower at all times because future emissions are tied to a lower 1990 reference value of 4.09 GtC/yr. For the residual, the situation is less clear and different choices are possible. The 1990 value must be higher (viz. 2.01 GtC/yr instead of 1.51 GtC/yr), because all cases have the same 1990 value for global emissions (6.10 GtC/yr). In the year 2000 and subsequently, we could either retain the IS92 values used previously (viz. 2.00 GtC/yr in 2000 for the IS92*a* case, etc. — see Figure 2 in the main text), or we could inflate all values by the 1990 “error” of 0.5 GtC/yr (i.e., retain the IS92 changes rather than their absolute values). The first method produces global emissions

[27] Note that it is not clear how bunker fuels will be considered in any legal instrument regarding emissions limitations, nor how or if the global bunker fuel component of emissions could be apportioned between Annex I and non-Annex I countries. We have therefore assumed throughout that the Annex I component of emissions does not include this term.

[28] Note that there is no information on future emissions from combustion of bunker fuels, so these are not accounted for. Since this small component would be common to both the original and modified emissions scenarios, neglecting it will not affect the results in any noticeable way.

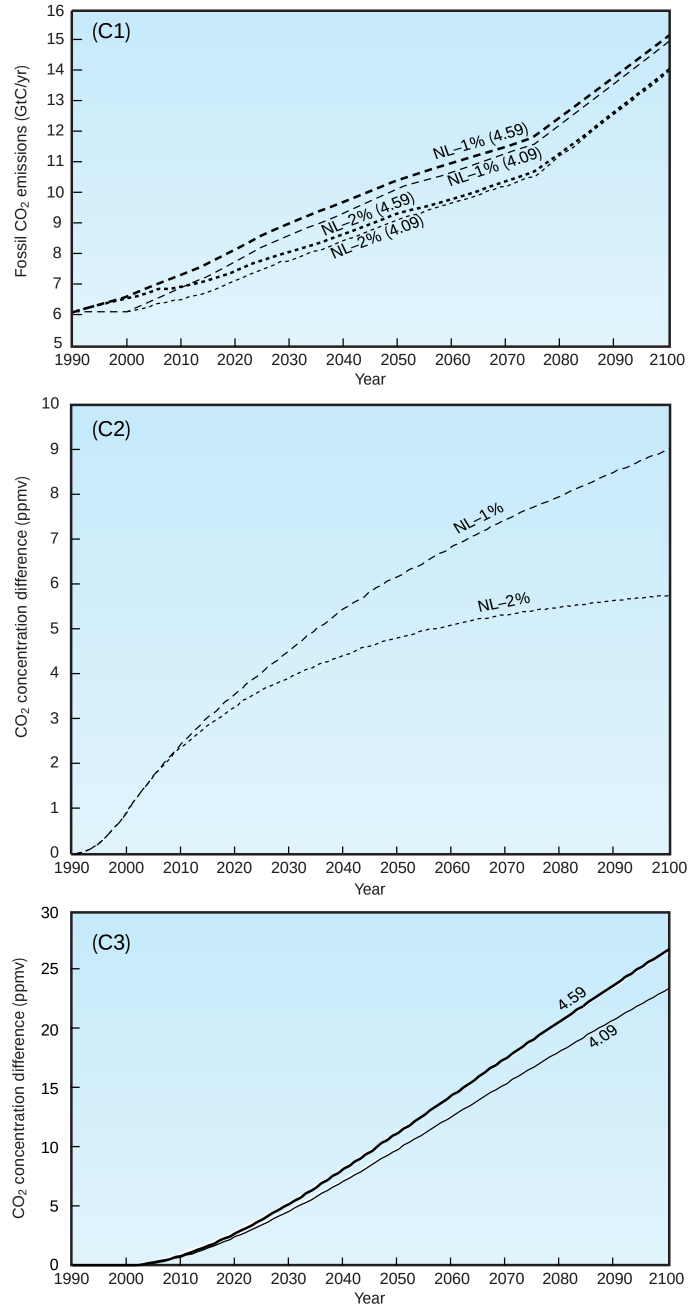


Figure C1. Global fossil CO_2 emissions (GtC/yr) where Annex I country emissions follow the NL-1% and NL-2% emissions limitation proposals and non-Annex I country emissions follow IS92*a*. The two pairs of curves give results for different values of the 1990 emissions level for Annex I countries, viz. 4.59 GtC/yr (as used in the main text) and 4.09 GtC/yr.

Figure C2. Sensitivity of CO_2 concentration projections (ppmv) to the assumed 1990 level of fossil CO_2 emissions in Annex I countries. The Figure shows CO_2 concentration differences for the NL-1% and NL-2% emissions limitation proposals for the case where 1990 Annex I country emissions are 4.59 GtC/yr (as used in the main text) minus the case where this emissions level is 4.09 GtC/yr. In all cases, non-Annex I country emissions follow IS92*a*.

Figure C3. Sensitivity of CO_2 concentration projections (ppmv) to the assumed 1990 level of fossil CO_2 emissions in Annex I countries. The Figure shows the difference in CO_2 concentrations between the NL-2% and NL-1% emissions limitation proposals for two different values of the 1990 emissions level, 4.59 GtC/yr (as used in the main text) and 4.09 GtC/yr. In all cases, IS92*a* emissions have been used for non-Annex I countries.

values that begin at the same point in 1990 and are lower than the original values for all subsequent years by amounts that increase linearly to 0.5 GtC/yr in 2000, and then decline to 0.18 GtC/yr in 2100 (for NL-1%) or 0.07 GtC/yr in 2100 (for NL-2%). The second method produces global emissions values that are unchanged over 1990–2000 and then exceed the original values by amounts that increase steadily to 0.32 GtC/y (or 0.43 GtC/yr) in 2100 for NL-1% (or NL-2%). Because the first method has much larger consequences for concentration in the near term, we consider only this case. We refer to the emissions defined under this method as NL-1%* and NL-2%*. The four global emissions trajectories (original and modified) are shown in Figure C1.

For the concentration implications, the effect of 1990 Annex I country reference emissions value may be viewed in two ways. First, we can see how the effect of the emissions limitation proposal (either NL-1% or NL-2%) depends on this value by comparing concentrations under NL-1% (or NL-2%) with those under NL-1%* (or NL-2%*). These concentration differences (i.e., NL-1% minus NL-1%* and NL-2% minus NL-2%*) are shown in Figure C2. In both cases the difference increases steadily reaching some 9 ppmv in 2100 for the NL-1% case and approaching 6 ppmv in 2100 for the NL-2% case. In terms of CO_2 radiative forcing in the year 2100, these differences amount to 0.1–0.2 W m^{-2}. The climate and sea level consequences of such uncertainties are extremely small; much less than uncertainties arising from other factors such as future non-Annex I country emissions under the IS92 scenarios, uncertainties in the emissions of other gases, climate and sea level model uncertainties, etc.

A second comparison is between different emissions limitation proposals: how sensitive, for example, is the difference in concentration between NL-1% and NL-2% to the assumed Annex I 1990 emissions values? These results are shown in Figure C3. Here, the effect is zero until 2000; the “error” then rises steadily to reach some 3 ppmv in 2100. The NL-1% versus NL-2% concentration differential of 27 ppmv in 2100 drops to around 24 ppmv for the lower reference level case. This is a negligible effect in terms of radiative forcing and climate consequences.

To summarize, in determining the absolute concentration changes for any given emissions limitation proposal, it is important to use the correct value for any reference emissions level. For comparing concentration projections between different proposals, however, if both proposals are based on the same reference level, concentration differences are relatively insensitive to the precise reference level value.

Appendix 4

GLOSSARY OF TERMS

Aerosol
A collection of airborne particles. The term has also come to be associated, erroneously, with the propellant used in "aerosol sprays".

Annex I Parties
Annex I of the United Nations FCCC comprises countries who were members of the OECD in 1992, countries undergoing the process of transition to a market economy, and the European Economic Community. The full list is given at the end of the Glossary.

Anthropogenic
Resulting from or produced by human activities. In the carbon cycle context this is taken as the direct input of carbon to the atmosphere as a result of human activities, the sum of the "fossil" and "land-use" components. It explicitly excludes contributions that arise purely as a result of increased CO_2 levels. In principle, anthropogenic emissions ought to include any changes in CO_2 fluxes associated with other man-made global change. However, in the present analysis any such fluxes would be included in the "CO_2 fertilization" (q.v.) component in order to balance the budget.

Carbon cycle
The term used to describe the exchange of carbon (in various forms, e.g., as carbon dioxide) between the atmosphere, ocean, terrestrial biosphere and geological deposits.

Climate
Climate is usually defined as the "average weather", or, more rigorously, as the statistical description of the weather in terms of the means and variabilities of relevant quantities over periods of several decades (typically three decades as defined by WMO). These quantities are most often surface variables such as temperature, precipitation, and wind, but in a wider sense the "climate" is the description of the state of the whole climate system.

Climate change (FCCC usage)
A change of climate attributed directly or indirectly to those human activities that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods.

Climate change (IPCC usage)
IPCC usage of the term "climate change" refers to any form of change due to human activities and/or natural processes. Climate change occurs because of internal changes within the climate system or in the interactions between its components, or because of changes in external forcing either for natural reasons or because of human activities. Projections of future climate change reported by IPCC generally consider only the influence on climate of anthropogenic increases in greenhouse gases and other human-related factors.

Climate sensitivity
In IPCC reports, climate sensitivity usually refers to the eventual (equilibrium) change in global mean near-surface air temperature following a doubling of atmospheric CO_2 concentration. More generally, it refers to the equilibrium change in near-surface air temperature following a unit change in radiative forcing (q.v.) at the top of the troposphere (q.v.) (°C/W m^{-2}).

CO_2 fertilization
Strictly, this is the enhancement in the net primary productivity of terrestrial vegetation (plant growth) that occurs as a biological process as a result of elevated atmospheric CO_2 concentration. In practice, in standard carbon cycle model calculations, CO_2 fertilization acts as a sink term that includes all changes in terrestrial carbon that are not associated with land-use change.

Fossil CO_2 emissions
This includes all anthropogenic (q.v.) contributions to the net atmospheric carbon budget, except for those classified as associated with land-use change. In practice, the contributions are those from fossil fuel combustion (including gas flaring) and cement production.

Greenhouse gas
A gas that absorbs radiation at specific wavelengths within the spectrum of radiation (infrared radiation) emitted by the Earth's surface, the atmosphere and clouds. The greenhouse gas, in turn, emits infrared radiation from a level where the temperature is colder than the surface. The net effect is a local trapping of part of the absorbed energy and a tendency to warm the planetary surface. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Halocarbons (q.v.) are also strong greenhouse gases. Note that FCCC usage sometimes employs the term "greenhouse gas" in a restricted way that excludes gases controlled under the Montreal Protocol.

Halocarbons
Compounds containing either chlorine, bromine or fluorine and carbon. Many of these compounds contain hydrogen as well.

Such compounds can act as powerful greenhouse gases (q.v.) in the atmosphere. The chlorine- and bromine-containing halocarbons are also involved in the depletion of the ozone layer. Specific types of halocarbon are: the CFCs (chlorofluorocarbons), containing only chlorine, fluorine and carbon; the HCFCs (hydrochlorofluorocarbons), containing hydrogen as well; the HFCs (hydrofluorocarbons), containing hydrogen, fluorine and carbon; and the halons, which contain carbon, fluorine and/or chlorine, and bromine.

Montreal Protocol
The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, subsequently modified in London (1990), Copenhagen (1992), Vienna (1995) and Montreal (1997) controls the consumption and production of chlorine- and bromine-containing chemicals that destroy stratospheric ozone.

Profile
A smoothly changing set of concentrations representing a possible pathway towards stabilization. The word “profile” is used to distinguish such pathways from emissions pathways, which are usually referred to as “scenarios” (q.v.).

Radiative forcing
A simple measure of the importance of a potential climate change mechanism. Radiative forcing is the perturbation of the energy balance of the Earth-atmosphere system (in W m^{-2}) following, for example, a change in the concentration of carbon dioxide or a change in the output of the Sun. The climate system responds to the radiative forcing so as to re-establish the energy balance. A positive radiative forcing tends to warm the surface and a negative radiative forcing tends to cool the surface. The radiative forcing is normally quoted as a global and annual mean value. A more precise definition of radiative forcing, as used in IPCC reports, is the perturbation of the energy balance of the surface-troposphere system, after allowing for the stratosphere (q.v.) to re-adjust to a state of global mean radiative equilibrium (see IPCC 1994 Report; Shine, *et al.*, 1995). Sometimes called “climate forcing”.

Scenario
A plausible description of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces (e.g., rate of technology changes, prices). Note that scenarios are neither predictions nor forecasts.

Stratosphere
The highly stratified and stable region of the atmosphere above the troposphere (q.v.) extending from the tropopause (q.v.) (about 9 km in high latitudes to about 16 km in the tropics on average) to about 50 km.

Tropopause
The boundary between the troposphere (q.v.) and the stratosphere (q.v.).

Troposphere
The lowest part of the atmosphere from the surface to about 10 km in altitude in mid-latitudes (ranging from about 9 km in high latitudes to about 16 km in the tropics on average) where clouds and “weather” phenomena occur. The troposphere is defined as the region where temperatures generally decrease with height.

ANNEX I PARTIES TO THE FCCC

Australia
Austria
Belarus
Belgium
Bulgaria
Canada
Czechoslovakia
Denmark
European Economic Community
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Japan
Latvia
Lithuania
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Romania
Russian Federation
Spain
Sweden
Switzerland
Turkey
Ukraine
United Kingdom of Great Britain and Northern Ireland
United States of America

Appendix 5

ACRONYMS AND ABBREVIATIONS

AGBM	Ad hoc Group on the Berlin Mandate (of the United Nations FCCC)
AOSIS	Alliance of Small Island States
CFCs	Chlorofluorocarbons
COP	Conference of the Parties (to the United Nations FCCC)
Dn80s	Net land-use change emissions averaged over 1980s. Dn = net Deforestation
EIS	Energy and Industry Subgroup
EU	European Union
FCCC	Framework Convention on Climate Change
ghg	Greenhouse gases
GNP	Gross National Product
GWP	Global Warming Potential
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
IS92	IPCC emissions scenarios defined in the Supplementary Report to the IPCC Scientific Assessment (1992)
OECD	Organization for Economic Cooperation and Development
PFC	Perfluorocarbon
QELROs	Quantified Emission Limitation and Reduction Objectives
S Profiles	The CO_2 concentration profiles leading to stabilization defined in the IPCC 1994 Report (Schimel, *et al.*, 1995) and Enting, *et al.* (1994)
SAR	IPCC Second Assessment Report
SBSTA	Subsidiary Body for Scientific and Technological Advice (of the United Nations FCCC)
TP	IPCC Technical Paper
WGI, II, III	IPCC Working Groups I, II, III
WMO	World Meteorological Organization
WRE Profiles	The CO_2 concentration profiles leading to stabilization defined by Wigley, *et al.* (1996)

Abbreviations used to denote emissions limitations proposals made by various Parties:

AOSIS	Alliance of Small Island States
AT	Austria
BE	Belgium
CH	Switzerland
DE	Germany
DK	Denmark
EU	European Union
FR	France
NL	Netherlands
UK	United Kingdom
ZR	Zaire (Now Democratic Republic of Congo)

Chemical symbols

Br	Atomic bromine
CFC-11	$CFCl_3$, or equivalently CCl_3F (trichlorofluoromethane)
CFC-12	CF_2Cl_2, or equivalently CCl_2F_2 (dichlorodifluoromethane)
CH_4	Methane
Cl	Atomic chlorine
CO	Carbon monoxide
CO_2	Carbon dioxide
HCFC-134a	CH_2FCF_3
HCFC-22	CF_2HCl (chlorodifluoromethane)
N_2O	Nitrous oxide
NO	Nitrogen monoxide
NO_2	Nitrogen dioxide
NO_x	The sum of NO and NO_2
O_3	Ozone
OH	Hydroxyl
S	Atomic sulphur
SF_6	Sulphur hexafluoride
SO_2	Sulphur dioxide
SO_4^{2-}	Sulphate ion

Appendix 6

UNITS

SI (Système Internationale) Units

Physical Quantity	Name of Unit	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
thermodynamic temperature	kelvin	K
amount of substance	mole	mol

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10	deca	da
10^{-2}	centi	c	10^{2}	hecto	h
10^{-3}	milli	m	10^{3}	kilo	k
10^{-6}	micro	μ	10^{6}	mega	M
10^{-9}	nano	n	10^{9}	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{-18}	exa	E

Special Names and Symbols for Certain SI-derived Units

Physical Quantity	Name of SI Unit	Symbol for SI Unit	Definition of Unit
force	newton	N	kg m s^{-2}
pressure	pascal	Pa	kg $m^{-1}s^{-2}$ (=N m^{-2})
energy	joule	J	kg m^{2} s^{-2}
power	watt	W	kg m^{2} s^{-3} (= Js^{-1})
frequency	hertz	Hz	s^{-1} (cycles per second)

Decimal Fractions and Multiples of SI Units Having Special Names

Physical Quantity	Name of Unit	Symbol for Unit	Definition of Unit
length	ångstrom	Å	10^{-10} m = 10^{-8} cm
length	micron	μm	10^{-6} m
area	hectare	ha	10^{4} m^{2}
force	dyne	dyn	10^{5} N
pressure	bar	bar	10^{5} N m^{-2} = 10^{5} Pa
pressure	millibar	mb	10^{2} N m^{-2} = 1 Pa
weight	ton	t	10^{3} kg

Non-SI Units

°C	degrees Celsius (0°C = 273 K approximately) Temperature differences are also given in °C (=K) rather than the more correct form of "Celsius degrees"
ppmv	parts per million (10^{6}) by volume
ppbv	parts per billion (10^{9}) by volume
pptv	parts per trillion (10^{12}) by volume
bn	billion
bp	(years) before present
kpb	thousands of years before present
mbp	millions of years before present

The units of mass adopted in this report are generally those which have come into common usage, and have deliberately not been harmonized, e.g.,

kt	kilotonnes
GtC	gigatonnes of carbon (1 GtC = 3.7 Gt carbon dioxide)
PgC	petagrams of carbon (1PgC = 1 GtC)
MtN	megatonnes of nitrogen
tC	tonnes of carbon
TgC	teragrams of carbon (1TgC = 1 MtC)
TgN	teragrams of nitrogen
TgS	teragrams of sulphur

Appendix 7

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Appendix 8

LIST OF IPPC OUTPUTS

I. IPCC FIRST ASSESSMENT REPORT, 1990

a) **CLIMATE CHANGE — The IPCC Scientific Assessment.** The 1990 report of the IPCC Scientific Assessment Working Group *(also in Chinese, French, Russian and Spanish).*

b) **CLIMATE CHANGE — The IPCC Impacts Assessment.** The 1990 report of the IPCC Impacts Assessment Working Group *(also in Chinese, French, Russian and Spanish).*

c) **CLIMATE CHANGE — The IPCC Response Strategies.** The 1990 report of the IPCC Response Strategies Working Group *(also in Chinese, French, Russian and Spanish).*

d) **Overview and Policymaker Summaries, 1990.**

Emissions Scenarios (prepared by the IPCC Response Strategies Working Group), 1990.

Assessment of the Vulnerability of Coastal Areas to Sea Level Rise — A Common Methodology, 1991.

II. IPCC SUPPLEMENT, 1992

a) **CLIMATE CHANGE 1992 — The Supplementary Report to the IPCC Scientific Assessment.** The 1992 report of the IPCC Scientific Assessment Working Group.

b) **CLIMATE CHANGE 1992 — The Supplementary Report to the IPCC Impacts Assessment.** The 1990 report of the IPCC Impacts Assessment Working Group.

CLIMATE CHANGE: The IPCC 1990 and 1992 Assessments — IPCC First Assessment Report Overview and Policymaker Summaries, and 1992 IPCC Supplement *(also in Chinese, French, Russian and Spanish).*

Global Climate Change and the Rising Challenge of the Sea. Coastal Zone Management Subgroup of the IPCC Response Strategies Working Group, 1992.

Report of the IPCC Country Study Workshop, 1992.

Preliminary Guidelines for Assessing Impacts of Climate Change, 1992.

III. IPCC SPECIAL REPORT, 1994

a) **IPCC Guidelines for National Greenhouse Gas Inventories** (3 volumes), 1994 *(also in French, Russian and Spanish).*

b) **IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations,** 1994 *(also in Arabic, Chinese, French, Russian and Spanish).*

c) **CLIMATE CHANGE 1994 — Radiative Forcing of Climate Change and An Evaluation of the IPCC IS92 Emission Scenarios.**

IV. IPCC SECOND ASSESSMENT REPORT, 1995

a) **CLIMATE CHANGE 1995 — The Science of Climate Change.** (including Summary for Policymakers). Report of IPCC Working Group I, 1995.

b) **CLIMATE CHANGE 1995 — Scientific-Technical Analyses of Impacts, Adaptations and Mitigation of Climate Change.** (including Summary for Policymakers). Report of IPCC Working Group II, 1995.

c) **CLIMATE CHANGE 1995 — The Economic and Social Dimensions of Climate Change.** (including Summary for Policymakers). Report of IPCC Working Group III, 1995.

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

(Please note: the IPCC Synthesis and the three Summaries for Policymakers have been published in a single volume and are also available in Arabic, Chinese, French, Russian and Spanish).

V. IPCC SPECIAL REPORT, 1995

Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (3 volumes), 1995.

VI. IPCC TECHNICAL PAPERS

Technologies, Policies and Measures for Mitigating Climate Change — IPCC Technical Paper 1.
(also in French and Spanish)

An Introduction to Simple Climate Models used in the IPCC Second Assessment Report — IPCC Technical Paper 2.
(also in French and Spanish)

Stabilization of Atmospheric Greenhouse Gases: Physical, Biological and Socio-economic Implications — IPCC Technical Paper 3.
(also in French and Spanish)

Implications of Proposed CO_2 Emissions Limitations — IPCC Technical Paper 4.
(also in French and Spanish)

IPCC Procedures for the Preparation, Review and Publication of its Technical Papers

At its Eleventh Session (Rome, 11-15 December 1995), the Intergovernmental Panel on Climate Change adopted by consensus the following procedures for the preparation of Technical Papers.

IPCC Technical Papers are prepared on topics for which an independent, international scientific/technical perspective is deemed essential. They:

a) are based on the material already in the IPCC assessment reports and special reports;
b) are initiated: (i) in response to a formal request from the Conference of the Parties to the UN Framework Convention on Climate Change or its subsidiary bodies and agreed by the IPCC Bureau; or (ii) as decided by the Panel;
c) are prepared by a team of authors, including a convening lead author, selected by the IPCC Bureau, in accordance with the guidelines of the selection of lead authors contained in the IPCC Procedures;*
d) are submitted in draft form for simultaneous expert and government review at least four weeks before the comments are due;
e) are revised by the lead authors based upon the comments reviewed in the step above;
f) are submitted for final government review at least four weeks before the comments are due;
g) are finalized by the lead authors, in consultation with the IPCC Bureau which functions in the role of an editorial board, based on the comments received; and,
h) if necessary, as determined by the IPCC Bureau, would include in an annex differing views, based on comments made during final government review, not otherwise adequately reflected in the paper.

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> "This is a Technical Paper of the Intergovernmental Panel on Climate Change prepared in response to a [request from the United Nations Framework Convention on Climate Change]/[decision of the Panel]. The material herein has undergone expert and government review but has not been considered by the Panel for possible acceptance or approval."

* Preparation of the first draft of a report should be undertaken by lead authors identified by the relevant Working Group bureau from those experts cited in the lists provided by all countries and participating organizations, with due consideration being given to those known through their publication or work. In so far as practicable, the composition of the group of lead authors for a section of a report shall reflect fair balance among different points of view that can reasonably be expected by the Working Group bureau, and should include at least one expert from a developing country.