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INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

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May 12, 1995

*5/23/95
agreement signed
and mailed to
Haite*

Dear Lead Author:

Cambridge University Press has agreed to publish the Working Group III Second Assessment Report. We believe that this will ensure excellent promotion and distribution for the report.

One of the requirements established by Cambridge University Press is that ALL Lead Authors sign an agreement that assigns copyright to the IPCC and indicates that permission to use material from other publications has been obtained where necessary. I believe there are very few, if any, cases where permission to use material from other publications will be required. We will identify them during the editing process. Environment Canada will pay any fees needed to obtain permission to use material from other publications. I believe therefore that the agreement is a very reasonable one for Lead Authors.

PLEASE SIGN THE ENCLOSED AGREEMENT AND RETURN IT TO ME BY MAIL. THANK YOU VERY MUCH.

Sincerely yours,

Erik F. Haite
Head, Technical Support Unit
Working Group III, IPCC

MEMORANDUM OF AGREEMENT

made this day of 1995

BETWEEN the Syndicate of the Press of the University of Cambridge (hereinafter referred to as "the Syndicate") on behalf of the Chancellor, Masters and Scholars of the University of Cambridge of the one part

the Intergovernmental Panel on Climate Change represented by Mr. James P. Bruce, Dr. Hoesung Lee and Dr. Erik F. Haites (hereinafter called "the Proprietor") of the second part

Her Majesty the Queen in right of Canada, as represented by the Minister of Environment (hereinafter referred to as "Environment Canada") of the other part and

Prof. Joseph Stiglitz

hereinafter called "the Author," which expression shall where the context permits include the Author's legal personal representatives, heirs and assigns, of the other part. In the case of multiple authorship the word "Author" is used collectively and the signing authors each have equal rights and responsibilities under this Agreement.

WHEREAS the Syndicate has decided to publish at its own risk and expense a work edited by Mr. James P. Bruce, Dr. Hoesung Lee and Dr. Erik F. Haites (hereinafter called "the Editor"), who are all three members of the Proprietor, and provisionally entitled **Climate Change: Economic and Social Dimensions** (hereinafter called "the Work")

NOW IT IS HEREBY AGREED between the parties hereto as follows:

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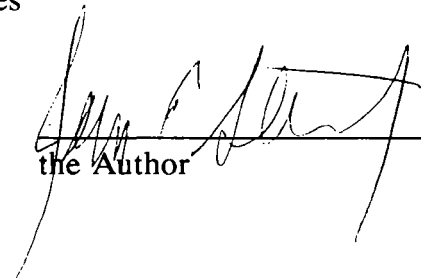
INTRODUCTION: SCOPE OF THE ASSESSMENT

(hereinafter called "the essay") to be included in the Work.

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7. The Editor shall deliver the Work in typescript in good order and acceptable to the Syndicate on or before August 31, 1995 failing which the Syndicate may cancel this Agreement.
8. This Agreement shall be interpreted in all respects in accordance with the Law of England.

9. Mr. James P. Bruce is authorized by Dr. Hoesung Lee and Dr. Erik F. Haites to sign on behalf of the Proprietor.

AS WITNESS the hands of the parties


the Author

for and on behalf of the Proprietor

for and on behalf of Environment Canada

for and on behalf of the Syndicate of the
Press of the University of Cambridge



DR. (MRS.) JYOTI K. PARIKH

Senior Professor

Ref : IPCC/JKP/95-ML

3rd March 1995

Dr. Joe Stiglitz
Council of Economic Advisors to the President
of the United States
Old Executive Building, Pennsylvania Avenue
Washington D.C., U.S.A.

Dear Joe,

1. I hope you find the revised chapter 2 satisfactory. We have taken care of many of your suggestions. Since this is not meant for highly technical audience, some footnotes you suggested would be kept when we publish it for a journal. If you are still unhappy, please let me know.
2. I am also happy to note that chapter 1 takes care of many of the suggestions we made. However, it mentions on page 41, (and also in the summary of the chapter, i.e. page 2, line 4) line 16 that FCCC recommends "equitable sharing". I did not find such a phrase in the FCCC. Perhaps you may wish to drop this but add separately what you feel about this. (This is mentioned twice).
3. You have mentioned one reference Parikh (1994) on Page 21, line 38, but it is missing from the reference list. It could be cited as follows : Parikh J.K. (1994), Vulnerability vs. responsibility in climate change outlook 94 proceedings, ABARE, Canberra, Australia, Feb. 1-4, 1994.

In addition, you may wish to cite the following two references.

4. In Kaya's identity GDP variable is missing. Therefore, I have added this in my enclosed paper. "North-South Issues in Climate Change". Since much of the growth in CO₂ emissions, even in developing countries will be due to GDP growth, this variable is important. Otherwise, here it is mentioned that lead of the North would have to be followed by South and that some developing countries may not belong to Non-Annex 1 group after sometime.

p. 2943

Ref : Parikh J. (1994b) North-South issues in Climate Change, Economic and Political Weekly, Vol. XXIX, No. 45-46, Nov. 5-12, Bombay, India.

5. Do you have any comments about the IGIDR paper I sent to you on "Efficient Emission Reduction through Joint Implementation" by P.G. Babu and Bibhas Saha.

With warm regards from both of us,

Yours sincerley,

Jyoti

Jyoti Parikh

End: "North-South Issues for Climate Change"

North-South Issues for Climate Change

Jyoti Parikh

Reprinted from *Economic and Political Weekly*, Vol XXIX, Nos 45 and 46, November 5-12, 1994
Pagination as in original

North-South Issues for Climate Change

Jyoti Parikh

The debate on climate change acquires a different dimension when the disparities between regions is considered in terms of responsibilities for emissions and concentrations and vulnerability to the effects brought on by climate change. This article reflects on North-South issues surrounding the climate change debate. The author also highlights certain issues which are difficult to address in conventional cost-benefit analysis.

GLOBAL climate change expected due to accumulation of greenhouse gases (GHG) in the atmosphere is a topic discussed by scientists, economists, and diplomats as the international negotiations and consultations are taking place at various levels on a regular basis in the recent times. At Earth Summit at Rio, heads of states signed conventions titled "Framework convention for climate change (FCCC)". This convention has since then been ratified by more than 50 countries and therefore, is now legally binding. However, many questions are still open. Since 70 per cent of annual GHG emissions are due to Annex I countries listed in the FCCC – also referred to here as 'North' or the developed countries – FCCC states that it is the responsibility of Annex I countries to lead the effort to reduce GHG emissions.

Carbon dioxide (CO₂) emissions due to fossil fuel burning, methane emissions due to livestock raising, chlorofluorocarbon emissions due to refrigeration and airconditioning systems are several among the many activities that are responsible for GHG emissions. Of these, CO₂ emissions due to fossil fuel burning is considered one of the crucial factor because of all pervasive role of fossil fuels in the economic development and because it accounts for nearly 60 per cent of GHG emissions. Therefore, energy policies of all countries are undergoing a review, especially of the countries in the North; those of the South too through aid agencies, multilateral agencies such as World Bank and Non-governmental organisations (NGO). Cumulated emissions due to fossil fuel burning from 1950 to 1990 is approximately 160 billion tons. However, current emissions due to fossil fuel are about 6 billion tons per year [CDIAC 1992] due to long life times of GHG: GHG emissions into the atmosphere raise the atmospheric GHG concentrations, which in turn, lead to climatic changes such as temperature changes, sea level rise, rise in frequency of extreme events such as floods, cyclones, typhoons and hurricanes, changes in precipitation, loss of species and so on. Unchecked GHG concentrations could lead to catastrophic consequences. It is uncertain when these effects will occur and due to how much GHG concentrations. However, it is clear that GHG emissions cannot be emitted without considerations for future. Given the limited amount of emissions that can be tolerated by the environment, there is a debate about who could emit how much in future.

This has direct bearing on what development alternatives are feasible in future for North and South.

The debate on climate change acquires a different dimension when the disparities between regions is considered in terms of responsibilities for emissions and concentrations (cumulated emissions) and vulnerabilities to the effects brought on by climate change. This article reflects on north-south issues surrounding climate change debate.

This article also highlights those issues which are difficult to address in conventional cost-benefit analysis, namely, equity issues and the need for collective decision-making; regional disparities in responsibilities; vulnerability of poor; effects on biosphere and biodiversity; present vs future generation; lead times required to correct the path; and how to meet the challenge.

REGIONAL DISPARITIES IN RESPONSIBILITIES

Regional shares of global carbon dioxide emissions are given in Table 1. The total share of the developed countries also referred as the North (that includes Australia/New Zealand and China is included in 'South') in total world emissions is 70 per cent in 1988 and 77 per cent in cumulated emissions over 1950-88. The ratio of per capita emission in developed and developing countries is 10. In the case of CO₂ emission from coal, it is 6 times. In case of oil, it is 10, in case of gas, it is 18.5. The ratios of per capita emissions in the US and India for solid, liquid fuel and total emissions are 14, 61 and 35 respectively. Total emissions by each fuel are given in Table 1. The cement manufacture also has a small share in the total emissions in the world. There also, developing countries' share is only about half. Thus, the primary responsibility of emission reduction lies with the North.

EQUITY ISSUES AND COLLECTIVE DECISION-MAKING

The major decisions concerning climate change that need to be faced by all countries and their citizens are:

What should be the level of concentration of GHG gases that can be tolerated at different times?

By how much should GHG emissions be reduced to achieve these chosen levels of tolerable concentrations?

How should these abatement levels be distributed among countries taking into account the responsibilities for current

concentrations and development needs? In other words, who should bear the burden of emissions abatement at different phases?

What kind of policies will achieve the desired reductions of concentrations of GHG gases and in turn, the emissions?

Considering that uncertainties will always remain, shall we wait for more precise information that reduces uncertainties? If we want to collect more information, and since collection of information is expensive, on what aspects of uncertainties should we concentrate? In this connection, we note that according to the earlier FPCC report, even present information is adequate to go for the goal of reducing global emissions by 60 per cent.

To answer these questions, a framework is needed which will be characterised by uncertainties at all levels.

It is fair to say that most decisions are made under some uncertainty or the other. Consider for example, the uncertainties in decision to invest in an energy supply system. During the lifetime of the project there could be changes in demand, interest rates, availability of alternative technologies and environmental and other regulations that may change from time to time. However, the uncertainties of climate change decision-making are characteristically different from other decisions because climate change decisions have to be taken collectively and not by a single entity; the consequences of these decisions affect everyone for a very long term and differently; any wrong decision made now can only be identified after a long lag, by which time it might be too late (distributional/regional effects); and it is subject to non-linear effects and can lead to large damages, irreversibility and catastrophic surprises.

Most important point about equity is that interests of all the stakeholders have to be considered fairly. Collective decision-making is essential when attention is paid to needs and vulnerabilities of others. Polluters cannot make decisions based on their cost benefit analysis alone when stakeholders are not just polluters. Adaptation burden passed on to others, and the environmental space needed for South and future generation to grow and develop, need to be considered. The question of comparison of living standards is most crucial.

POVERTY AND CLIMATE CHANGE

While the picture of division of responsibilities is clear, the picture of vulnera-

Sealing the Fate of Non-Maratha Castes

Suhas Palshikar

THIS is in response to Gail Omvedt's commentary on the demand for renaming the University of Poona ('Maharashtra: Politics of Culture', *EPW*, August 13, 1994). Phuley, Shahu and Ambedkar have become an important intellectual heritage for progressives (in particular in Maharashtra) and they together form a radical tradition. With a university named after Ambedkar and one (albeit agricultural) after Phuley it is only natural that the legacy of Shahu be fittingly recognised. Yet, as Omvedt's commentary suggests, the response of 'progressives' in Maharashtra to this demand is less than enthusiastic. Why? One put answer could be because all progressives (except those with the 'correct' political line, in this case the BSP line) are Brahmanic! On the other hand, it may also be noted that the 'politics' of making such a demand in the context of emergent OBC politics is an important reason behind the lukewarm response.

Gail Omvedt is right in saying that the demand for renaming Poona University after Rajarshi Shahu "is a political one, and it is on political grounds that it should be judged" (p 2128). Two points may be mentioned about this 'politics of culture'. Probably the proponents of this demand expect resistance from Brahmins/Hindutva parties whereby a cultural divide between Brahmanic Hindutva and Bahujan Samaj can be exposed. It would be naive to expect Hindutva forces to oppose this demand. In fact during the last phase of the Namantar movement (for renaming Marathwada University), the Sangh parivar's was among the most vociferous voices supporting the demand. Of late, the Sangh parivar is consciously subjecting itself to a changed social composition. This change leads to a changed public position on ideological and cultural issues also. At least, in the one month since the BSP made this demand formally on July 27 no public statement against the demand has come from the Hindutva forces. In such a situation, the 'political' aspect of the demand, viz, exposing Hindutva forces, is not likely to meet with much success. We have already witnessed skilful appropriation of Ambedkar and Phuley by Hindutva forces. The Samarasata Manch or inclusion of Phuley-Ambedkar in the daily prayer of RSS are only superficial examples. In Marathi, the writings of Sheshrao Moray¹ and S H Deshpande² have consistently argued Ambedkar's favourable inclination towards the Hindutva project. Therefore, Hindutva forces are not likely to

wage serious opposition to the demand of giving Shahu's name to Poona University. The fact that Shahu's name is associated with Shivaji will counterbalance Shahu's long-drawn battle with Brahman orthodoxy. And anyway, when the issue gathers momentum the Sangh parivar will definitely seize this opportunity for endearing itself to the bahujan masses by upholding the demand.

However, there seems to be another 'political' aspect of this demand which comes to the fore at the end of Gail Omvedt's report (p 2129). Bypassing the large sections of backward castes in the state, Kanshi Ram seems to be wooing the Maratha community. Gail Omvedt seems to be endorsing this when she says, "there is one final aspect of the BSP's version of 'bahujan' politics that comes forward clearly in the demand for taking Shahu's name. That is of course the recognition of the Maratha-Kunbi community as a major part of the 'Bahujan Samaj'."

Sadly enough, Shahu Maharaj is made a symbol attracting the Maratha-Kunbi community rather than the entire Bahujan Samaj. This goes against Gail Omvedt's own account of Shahu's contribution to the uplift and awakening of bahujans. Having thus confined Shahu to the pride of Maratha community, she goes on to argue that Marathas are not a powerful caste-group in Maharashtra.

The Maratha-Kunbi community definitely performed a historical role in leading the Brahmanetar movement and creating a 'bahujan' consciousness among the masses during the independence period. But after independence, this community alone made political gains grounding its politics in the bahujan ideology. The political and material gains made by the Marathas in the state have created a rupture between them and the rest of the Bahujans. Whether it be ministerial positions in the state cabinet or presidencies of zilla parishads or DCC banks or chairmanships of sugar co-operatives, the

majority of the occupants are Marathas. This is not an accident. Nobody claims that all Marathas are powerful. Yet the fact that political and material power in the state is controlled by the Maratha leadership cannot be denied. Against this background the claim that Marathas form a major part of the Bahujan Samaj can be nothing but legitimisation of the present Congress-dominated politics in the state. By wooing the Marathas, the BSP is trying to run away from the real confrontation – the one against the Congress.

Further, Gail Omvedt has also challenged the Maratha/Kunbi distinction. True, the ground level reality of Maratha-Kunbi relationship is complicated. And yet, is it not a fact that Kunbis find a place in the list prepared by the Mandal Commission and the Marathas do not? Once we are tempted to deny any distinction between Kunbis and Marathas, we come dangerously close to the position of the Maratha Mahasangh. Given its pro-Maratha position, it seems that the BSP may not, after all, be averse to making friends with the likes of the Maratha Mahasangh. This will lead it to a big brotherly or patron-like indulgent attitude towards the non-Maratha castes.

Ideologically, if the Bahujan ideology is to lead us anywhere, then it has to turn to the non-Maratha castes. It is not merely a question of majority or numerical strength. The concept 'bahujan', connotes concern for the deprived masses and a promise of bringing them to the political forefront. "Bidding for Kunbi-Maratha support" (p 2129) and mute recognition of the leading role of the Maratha community at this juncture is a strategy which is bound to seal the political fate of non-Maratha castes at least for another decade.

Notes

- 1 Sheshrao Moray, 'Savarkarancha Buddhivad Ek Chikitsak Abhyas', Nirmal Publication, Nanded, 1988, and 'Savarkarancha Samajkaran: Satya ani Viparyas', Rajhans Publication, Pune, 1992.
- 2 S H Deshpande, 'Savarkar te Bhajapa: Hindutvavicharacha Chikitsak Alekh', Rajhans Publication, Pune, 1992.

For the Attention of Authors

The compulsion to limit the size of issues on account of steeply rising newsprint and other costs and a sizeable backlog of material awaiting publication lead us to request that papers submitted for publication be not over 10,000 words, including tables and notes and references.

It is helpful if contributions in word-processed format are accompanied by floppy disc copies, in Wordstar preferably. The latter will be returned after use.

people from Maldives? Unfortunately, burden of adaptation is too vague to seek for compensation. Since there is no way of recovering this liability after 50 years from generations that may have caused the damage and that may no longer exist, best course is stronger mitigation by the North now. Mechanisms for transfer can range from transfers through carbon tax collected in the North, technology transfer, joint implementation tradable quotas, super funds and so on.

LEAD BY NORTH TO BE FOLLOWED BY SOUTH

FCCC expects Annex I countries to take the lead in reducing CO₂ emissions as they account for 75 per cent of global emissions. How does one envisage a global emission reduction scenario in this context? Average per capita emission levels provide a criterion that provides some guidelines. Although, this is not explicitly stated in the FCCC, it is this criterion that puts Denmark and Netherlands in Annex I category and China and India in the other. Those who have less per capita emissions than world average have less responsibility. The disparity can be gauged by the fact that about three-fourth of population have less than the world average consumption. Per capita emission is also an indirect indicator of living standards. Till such standards are achieved, it will be unfair to ask them to reduce. If all countries had the living standards similar to those in India and China, there would not have been concentrations accumulated as of today and the problem could have been postponed by many decades.

Let us turn to Kaya identity which says

$$\begin{array}{c} \text{carbon} \\ \text{emission} \end{array} = \begin{array}{c} \text{carbon} \\ \text{intensity} \end{array} \times \begin{array}{c} \text{energy} \\ \text{consumption} \\ \text{of energy} \\ \text{system} \end{array} \times \begin{array}{c} \text{N} \\ \text{popu-} \\ \text{lation} \end{array} \quad (1)$$

This identity needs to be modified to include GDP for better understanding about the role of economic development.

$$\begin{array}{c} \text{carbon} \\ \text{emission} \end{array} = \begin{array}{c} \text{carbon} \\ \text{intensity of} \\ \text{energy system} \end{array} \times \begin{array}{c} \text{energy} \\ \text{intensity} \\ \text{of GDP} \end{array} \times \begin{array}{c} \text{N} \\ \text{population} \end{array} \times \begin{array}{c} \text{Y} \\ \text{GDP per} \\ \text{capita} \end{array} \quad (2)$$

Parikh's modification of Kaya identity helps us to see the consequences associated with emission stabilisation or reduction. The rate of change in carbon emissions from equation (2) can be seen as below:

$$\begin{aligned} \frac{dC}{dt} &= \frac{C}{E} \times \frac{E}{Y} \times \frac{Y}{N} \times \frac{dN}{dt} + \frac{C}{E} \times \frac{E}{Y} \\ &\times \frac{d(Y/N)}{dt} \times N + \frac{C}{E} \times \frac{d(E/Y)}{dt} \times \frac{Y}{N} \times N \\ &+ \frac{d(C/E)}{dt} \times \frac{E}{Y} \times \frac{Y}{N} \times N \quad (3) \end{aligned}$$

It is clear that in the near future, population decrease or per capita GDP decrease are not plausible alternatives. Thus, carbon intensity of energy system and energy intensity of GDP not only have to be reduced to compensate for increase in carbon due to increase in GDP and population but also go beyond that, if total emissions have to be reduced.

Parikh identity also suggests that in the long-term population reduction, GDP stabilisation and other such measures that may be considered drastic by today's standards, will be in the arena of desirable options, if climate change problem turns out to be more serious than it appears today.

CHANGE OF RATE OF GROWTH

Before one stabilises, or reduces carbon emissions, one usually has to change the growth rates (if a monotonic function, i.e., d^2C/dt^2 turns zero or negative first, before dC/dt does). Equation (3) for dC/dt suggests that a second derivative of Parikh identity could lead to 16 terms. To put it simply, first, one stops growing the ever increasing growth rate. For example, fossil fuel growth rates in North used to be in the range of 3 per cent to 7 per cent in the 70s, which has come down to 0 per cent or ± 1 per cent. On the other hand, emission growth rates in South increased till 90s but are showing signs of deceleration in many major countries such as India and China due to reduced population growth, but mainly due to reduction in energy intensity of GDP (E/Y) and to some extent in carbon intensities (C/E). Yet, these growth rates are at high level and further reduction in these growth rates is required after which they will also have to be stabilised of course, after many decades. A plausible "time table" of how the lead taken by Annex I countries can be followed up by Annex II is indicated in Table 2.

HEDGING STRATEGIES TO FACE CHALLENGE

Summarising this, one can say that in order to meet the challenge, consider hedging by actions on four fronts:

- Obtain better information from R and D on how serious is the challenge and to reduce uncertainties in global warming and its likely impacts. Although, this information is extremely valuable, one cannot wait till it arrives because of the uncertainties and lag times associated with all R and D activities in general and climate change in particular.
- Develop technologies for reducing dependence on fossil fuels. This includes non-fossil technologies i.e., renewable sources such as solar, wind or biomass on rotation basis as well as energy efficient technologies.
- Explore cheaper investment opportunities in the South and reduce their rise in emissions through energy efficient technologies and different development patterns. Consider this also as compensation

mechanisms from the North under pollution-pay-principle. Global Environmental Facility set up recently to serve the requirement by FCCC to find incremental costs.

- Deal with the larger issue of change in consumption patterns in the North and subsequently South.
- North-South transfers are inevitable whether one considers rent of the environmental space, third party insurance for vulnerable poor, transfers by collecting carbon tax in the North, technology transfer, joint implementation for carbon reduction projects or tradable permits. Not all of these are mutually exclusive.

Note

[This is a revised version of paper that was presented at 'Outlook 94' organised by ABARE, Canberra, Australia, during February 1-3, 1994, and later at Montreux, Geneva, in March 1994. I am grateful to P G Babu for his valuable comments and Kavikumar for research assistance. Mahesh Mohan has patiently typed various versions of this paper.]

* If the world had a balanced development, everyone would have a carbon emissions entitlement of 1.1 t per year. Due to the skewed income distribution, in 1990 the ICs emitted 75 per cent of emissions, rather than their share of 25 per cent, of the total emissions of 5.6 billion tons. Fifty per cent of 5.6 billion tons is 2.8 billion tons of excess emissions, which is the extent of environmental subsidy provided by the DCs to the ICs. It is assumed that while the first billion tons could be reduced at a cost of \$ 15 per ton, the next 2 billion tons would cost much more, since the cost rises exponentially. Assuming, for simplicity, an average cost of \$ 25 per ton for the entire 2.8 billion tons of emissions, the South-North transfer or subsidy is approximately \$ 70 billion equivalent per year.

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to survive, e.g. public transport. There is a large class of those who would rather not drive, e.g. aged, handicapped, children, tourists and other visitors, and need these options. They either forgo travel or are dependent on others who could drive. They put demand on other persons time, which should be also valued. Often women bear this burden. Many mothers stay home so they can drive their children to school and back.

Thus, fortunately, reducing CO₂ emissions can be almost viewed as a by-product of these other activities, which are also important to the North in terms of tangible benefits. Lead times being large, if at least some actions are initiated, progress would have been made by the time more conclusive evidence comes.

Unfortunately, "no-regret" can have different meanings to different people. What is meant here is more proactive policies than these as if climate change problem does not exist.

PRESENT VS FUTURE GENERATION

It is argued by T Schelling (1993) that if the North cumulates what it would pay for global warming with a discount rate, it could mean trillions of dollars for future generations. The North could spend the same or even a small portion of it for development assistance for present generation instead. Since a large percentage of future generations will be from the South, a choice to spend on global warming by the North, prefers future generation in the South rather than the present generation of the South.

These arguments which appear to be rather persuasive, exclude one important possibility viz. paying for energy efficiency projects in the South now which helps present generation by reducing fossil fuel bills and also reduces fuel related emissions, local and global. The latter helps the future generation of the South and North as well. Thus, there need not be conflict or trade off between the two objectives of dealing with global warming and helping the South at present. Moreover, if joint implementation (JI) is permitted, it can even help present generation in the North by providing cheaper option to reduce emissions at around US\$ 15 per tonne carbon, achieved by Global Environment Facility (GEF) as compared to about \$ 640 per tonne of avoided carbon emissions using backstop technologies of non-fossil fuel variety such as renewable energy technologies, e.g. solar and wind [A Manne and Richels 1992]. Of course, under tradable permit scheme, developing countries could receive market-cleared price which will be much higher than incremental costs given by the GEF or project-based costs which may be given under joint implementation schemes. Thus, both of these are inferior to tradable permits scheme from the viewpoint of the South.

EMISSIONS FROM SOUTH IN PERSPECTIVE

South has not benefited from the pollution as the North has. It is not correct to say that

everyone emits. There is a difference between those who emit more than their share of absorption capacity of the atmosphere on per capita basis and those who emit less than that. This range can be approximately 0.5t to 0.6t per person, based on the fact that out of nearly eight billion tons emitted by 6 billion persons, 3 to 4 billion tons is absorbed by various mechanisms such as oceans, forests, agriculture and other – i.e. 0.6t per capita emissions may be considered acceptable levels. This is the same as China's current emissions. If absorption capacity is difficult to allocate on per capita basis, another basis could be to decide, on the basis of per capita emissions below the world average (1.15 t in 1990) and above the world average. Third basis to assign responsibility could be that based on the marginal damage. If concentrations from the North from 1950 onwards are put to zero, then the South could go on for another century or longer without a concern for climate change. If emissions from 1990 onwards of North are put to zero, South can still begin to clean up existing concentrations because South's emissions are below the atmospheric cleansing capacity. Then South could in future reach much higher stabilisation levels than is possible, if North keeps emitting at the present or even at reduced rate. On the other hand, North needs to reduce, even if emissions or concentrations from South from 1990 are put to zero. This criteria is a marginal damage principle, and can be useful to decide when non-Annex 1 shall reduce.

While the concentration liability before 1990 could be dealt with separately, it is important to stop free-riding immediately. International negotiations take a long time to stop free riding by the North. For this purpose, concentration levels of each country after 1990 should serve as a bench-mark for all possible future negotiations. This leads us to the next issue of North-South transfer. This would prevent free riding and precipitate some action even while matters are being negotiated. While issues such as past concentrations, population can be discussed later, accepting this principle of accountability after 1990 could lead to prudent behaviour and act as some deterrent to all against wasteful consumption.

NORTH-SOUTH TRANSFERS

North-South transfers are justified on several grounds as suggested below. These grounds are not mutually exclusive; that is,

if payment is made for one, it could sometimes – but not always – exclude the other. The basis for North-South transfers are not just the past concentrations, but also higher emissions after 1990 and liability for adaptation and irreversible damages.

(a) North is using environmental space far larger than its fair share, whichever way one works that out. Parikh (1994) calculates the worth of this space to be \$ 70 billion per year,* which is made available at present by South to North. Of this, India accounts for nearly one-fourth. This can be considered equivalent to the rent of the environmental space.

(b) If 'polluters pay principle' applies to local pollution, why not also to global pollution?

(c) North's consumption patterns have put development plans of South in jeopardy. South can no longer plan their development strategy, as if climate change issues do not exist, the freedom that North enjoyed up-till now. Parikh and Gokarri (1993) calculate that just a small shift of energy conservation policy from saving oil to saving coal can cost India \$ 300x10⁶ (1989-90 prices) simply in fuel substitution alone, excluding capital costs for that change. They suggest that these are economy-wide incremental costs which result from diversion of national policies to work on climate change issues. Thus, this component is due to small amount of mitigation expected from South. Climate change issues also divert attention of policy-makers, scientists and NGOs, often the first rate ones, from more pressing issues.

(d) Third requirement for North-South transfer comes from the impacts of climate change that South will undergo for no fault of its own. These impacts are of two types: irreversible damage costs to be compensated and adaptation costs imposed due to delay by North in mitigation. The climate change liability for irreversible damages is likely to be too high to be insured first, to those who will be affected by it. The damage/adaptation costs ranges from costs due to increased occurrence of extreme events, loss of livelihood from fishing, farming; loss of lives due to heat, higher cooling costs, and many other adaptation costs Cline (1992). Although, insurance can be another form of transfer. Will the North pay for dykes in Bangladesh or give migration rights and compensate for shifting and rehabilitation to

TABLE 2: ILLUSTRATION OF STRATEGIC DECISIONS TO BE TAKEN IN SEQUENCE BY NORTH AND SOUTH

Time Period	Growth Rate of Emissions (dC/dt)		Rate of Change of Growth (d ² C/dt ²)	
	Annex I Countries	Non-Annex I Countries	Annex I Countries	Non-Annex I Countries
Up to 1990	≥ 0	> 0	≤ 0	> 0
1990-2000	= 0	> 0	< 0	> 0
2001-2025	< 0	> 0	< 0	= 0
2026 - 2050	< 0	≥ 0	< 0	< 0
Beyond 2050	≤ 0	≤ 0	< 0	< 0

C: Annual carbon dioxide emissions.

bilities is unclear. For example, increased occurrence of floods and other extreme events such as cyclones, hurricanes are indicated due to global warming. In general, the poor are always more vulnerable to any calamity compared to well-off. For example, in the recent earthquake at Latur in India, more than 10,000 people died compared to less than hundred in the earthquake of the similar intensity in California. Nearly half of Bangladesh could be expected to submerge due to increased floods and sea level rise increasing poverty and homelessness. While the Netherlands can build more dikes, for protection against sea level rise, Bangladesh cannot do the same. Will Bangladesh be insured against this by those who emit more GHGs? Some island states fear disappearing from the map of the earth. Will they be assured of immigration rights to the developed countries and compensations from the damage?

Large-scale out-migration from coastal zones is expected due to sea level rise. Intrusion of sea water in the ground water and changes in temperature can reduce agricultural incomes everywhere. In Bangladesh share of GDP due to agriculture is 38 per cent compared to only 3 per cent of GDP in the US [World Bank 1992]. Share of population depending on agriculture is also more than 60 per cent of the population in Bangladesh. Thus, impacts of climate change on poor peasants of the South will be higher.

Thus, the poor lose control over their destinies, their land due to increased need for forests and sea level rise, their agricultural incomes, their livelihood, say, from fisheries, and their homes, if they live on coastal zones. For example, more than seven million persons may be displaced from central zones in India. Large cities like Bombay, Calcutta and Madras are on the coast. Deaths and discomforts are indicated due to heat stress.

Rising concentrations will bring constraints on their future development. Thus, the poor (South) will pay for the lifestyles and consumption patterns of the rich (North).

While the rich can argue about whether to enjoy more now or pay for future, and what discount rates to use, this is not the issue for poor. While the rich can ponder what trade off between present generation's comfort vs future generation's comfort, and the appropriate discount rates, the issues facing poor are quite different.

ANTHROPOCENTRIC VS ECOCENTRIC EVALUATION

Even more vulnerable than poor people are flora and fauna whose plight is difficult to judge by the mankind.

Earlier IPCC impact assessment indicates substantial pressures on biosphere and biodiversity due to climate change. For example, bleaching of coral reefs is expected. Due to upward movement of only the temperature zones (without the rest of the

ecosystem that provides life-system support for the species), loss of species is also indicated.

Loss of species or damage to biodiversity has been ignored in the decision-making in the past. Only recently, concern for biodiversity is expressed in the environmental impact assessment framework. Even efforts for valuation of biodiversity and ecosystem or biosphere are also made.

However, all these efforts put mankind at the centre around which the rest of the biosphere revolves. Cost-benefit analysis is done valuing species for the pleasure and service of mankind, be it for recreation, medicines, education, research, chemicals, biochemical and other ingredients or to derive raw materials for a variety of purposes. Cost-benefit analysis approaches, even if they include valuation of biodiversity or services of biosphere, are anthropocentric.

Is judgment of mankind sufficient to determine what should exist, how much and why? Being the most intelligent of species, it is very much in a controlling position. Is this position not misused, if extinction of large part of biodiversity and degradation of ecosystem are brought about despite knowledge and even warnings?

Ecocentric view, on the other hand, views mankind as one of the species on the planet earth. It is expected to live in harmony and balance with not just other species but share the rest of biosphere including oceans, atmosphere, rivers, and so on which provide sustenance to others. It does not make judgment on other species but judges itself from the view point of others. If other species were to judge mankind by pressure on earth's resources, what would be their judgment on ourselves? Civilisation is about strong protecting the weak.

Should not mankind alter certain consumption patterns, if its activities directly or indirectly harm other species? Who speaks on behalf of flora, fauna and biosphere? When nature loses, can mankind win? Are we not all losers?

LAG TIMES FOR CLIMATE CHANGE VS LEAD TIMES FOR TRANSITION

It is said that serious effects of climate change are more than 50 years away. But the lead times for transition of energy system can be also very large – say 50 to 100 years or more. Although, there is much discussion about alternative fuels and renewable energy, their share in the total energy supply has not increased in the last two decades. If no measures are taken while we wait for scientific uncertainties to resolve, the problem becomes much bigger. What if, in the end it turns out that the climate change problem is very much there or even worse than we expected? Or that even after 10 years of research we do not resolve uncertainties, and continue to emit in the hope of good news with a very small probability that somehow the issue will disappear? Those who are at risk, watch rising concentrations helplessly. Rising concentrations do mean less development in future for them. Moreover, the risk for poor is much worse than for others. Some hedging is required for them. At least regular deposits in some fund to take care of poor in the developing world is necessary.

Can polluters decide how much they wish to abate based on discount rates of their own choice? Discussion on discount rates is incomplete, if we do not consider lead times involved.

Lead times are not in terms of technology alone, lead times are also required to take people along and not just the scientists, or the government – to accept the responsibility, to agree to act, to decide how to act, to find resources for the plan of actions, and to implement and monitor plan of actions.

Democratic processes are slower than one realises. Therefore, those "no-regret" actions should be initiated which are also in the interest of the North in terms of reducing local air pollution, reducing fuel bills, formulate pricing policy to encourage fuel substitution and to provide other diverse options to people to choose from. Low fossil fuel prices make it difficult for other modes

TABLE 1: PATTERNS OF ENERGY CONSUMPTION AND CO₂ EMISSIONS (1989)

Items	World Total (MMTOE)*†	Share (Per Cent) Dvlpd	Share (Per Cent) Dvlpg	Per Cap (Kg OE) Dvlpd	Per Cap (Kg OE) Dvlpg	Dvlpd/ Dvlpg	USA/ India
Fuel and Electricity							
Solid	2309	66	34	1278	199	6	14
Liquid	2745	75	25	1720	175	10	61
Gas	1611	85	15	1147	61	19	227
Electricity	343	81	19	230	17	13	46
Total	7009	75	25	4376	453	10	35
Global Emissions							
Total Emissions	5723	70	30	3.36	0.43	8	27
Cum Total Emissions (50-88)	112060	77	23				
Solid	2413	64	36	1.31	0.22	6	14
Liquid	2205	70	30	1.33	0.16	8	54
Gas	907	82	18	0.62	0.03	21	228
Flaring	48	25	75	0.01	0.01	1	4
Cement	148.8	49	51	0.06	0.02	3	6

Source: J Parikh et al (1992), 'Consumption Patterns: The Driving Force of Environmental Stress', IGDDR Monograph.

PHOTOCOPY
PRESERVATION



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

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Handwritten signatures: "SK" and "RS"

MEMORANDUM

TO: Dr. William Cline
Dr. Joseph Stiglitz
Prof. Ken Arrow
Dr. Mohan Munasinghe
Prof. Karl Goran-Maler

FROM: Dr. Erik Haites *EH*

RE: Comments on Chapter 4

DATE: March 24, 1995

Here is a complete set of comments on Chapter 4 for your review. We have also enclosed a diskette copy in WordPerfect 5.1 of this.

We would like to have another draft of your chapter for review by the Bureau by April 24. If possible, please provide an electronic copy (WordPerfect 5.1) of the revised chapter.

Chapter Four

WOMEN Governments/Organizations Review of the Second Assessment Report

Chapter 4: INTERTEMPORAL EQUITY AND DISCOUNTING

4.0	General Comments and <i>Summary</i>	<i>ii-iii</i>
4.1	Introduction	1-3
4.2	Intergenerational Equity	3-5
4.3	Discounting and the Social Rate of Time Preference	5-14
4.4	Formulation of Descriptive Approach	14-17
4.5	Discounting for Risk	17
4.6	Producer or Consumer Interest Rates?	17-19
4.7	Discounting Environmental Impacts	19-20
4.8	Implications for Sustainable Development	20-22
4.9.1	<i>Annex 4A</i>	23-26
4.9.2	<i>Endnotes</i>	27
4.9.3	<i>References</i>	28-33

Reference			Comments	Reviewer	ID	Response
Section	Page	Line		(Country #)		
04 Intertemporal Equity and Discounting						
0	0	0	This is a clearly written and rigorous exposition of discounting and inter-temporal equity. Is this topic, covered in 32 pages including references, of sufficient interest to policy makers and government delegations to form part of the main SAR? As a paper in a separate volume of Technical Papers it would have greater merit (some material in a few other chapters could be similarly handled). This material is familiar enough to those who follow the relevant academic literature, but there is widespread feeling that economists in this area wax over-long and over-enthusiastically on discounting and discount rates. The essence of the topic could be adequately covered in 2 or 3 pages and go into a slightly expanded section in Chapter 5 (pp. 32-33) or Chapter 6 (section 6.1.5 at p. 7). This proposal should not be viewed as a negative comment, but a reflection of the subject matter and its prioritisation for most potential readers. A box might have been prepared which summarised why some people are deeply opposed to the application of discounting (or maximisation of net present value) to intergenerational and other sustainable development issues.	WEC	01	A
0	0	0	It seems that the scientific information and the more personal views of the authors are not clearly separated. There is an obvious lack of coordination between chapters three and four. The key message seems to be that there are several arguments for choosing a high discount rate or a low one; the final choice is really up to the policy-makers. More attention could be paid to the (especially moral) implications of using a discount rate. The differences between prescriptive and descriptive need to be clearly stated.	NED	09	G
0	0	0	Re. page iii, line 12. What is the scientific basis for these numbers? Suggest deletion.	NED	09	G

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
0	0	0	General Comments 1) with strong arguments against using a non-zero pure rate of time preference can not see why a zero or at least a very low rate is not recommended in the text. 2) Discounting due to an expected increase in per capita income in the world is discussed and it is recognized that the relative per capita growth need not be constant over time. If it declines over time it implies that also the discount rate should decline. In combination with a low or zero rate of time preference, this has considerable implications for how impacts occurring far into the future are valued. This should have been illustrated in a diagram as well as mathematically. (See attachment)	SWED	17	G	
0	0	0	While it is true that "identifying the proper discount rate is probably the single most important analytical step in the economic analysis of climate change", the cited sentence might create the impression that one can analytically derive a value for the discount rate. This is impossible because one component of the discount rate must be determined by the pure time preference, must be determined by ethical considerations. Thus it should be stressed that (i) the discount rate is to a decisive extent determined by ethical considerations and (ii) the choice of crucial importance for the cost analysis of climate change.	SWED	17	G	
0	0	0	Can this issue meaningfully be expressed as a discounting problem? Much of the benefit that will take place far in the future cannot reasonably be estimated, it involves health and ecosystem effects which are ill-defined and whose valuation is uncertain and controversial. This suggests that a multi-criteria approach to the problem is more suitable. Suggest organizing the chapter along the following lines: - Economics provides no clear answers to many of the issues raised by discounting in this situation. There are strongly held views on all sides of the question. - The use of MCA provides an alternative to trying to discount the future benefits of current climate change mitigation strategies, although MCA is not without its own drawbacks. - There is a strong philosophical following for the use of low social discount rates for discounting future consumption, and a strong practical following for the use of rates nearer market levels.	IPIECA	18	A	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			Trying to value the effects of foregone investment on future consumption is complex and possibly subject to manipulation. It is hard to justify lower discount rates for this particular type of social investment than for the many other types of investment that are currently made. Faced with this dilemma, some analysts have chosen compromise rates between these positions. An alternative is the use of multiple discount rates by analysts. The implications of this approach, with all results provided to other analysts and policymakers, might usefully be addressed in this chapter.				
0	0	0	Re. p. ii, lines 3-7. The recognition that this is a philosophical and ethical question as well as an economic one is important. However, this also means that there can be no one right answer to the discount rate question. To communicate to policymakers the necessary absence of a "proper answer" to this question is important in an assessment of economic knowledge to the climate change question. Re. p. ii, lines 31-32. Consistent with the comments on lines 3-7 by this reviewer, avoid implications of there being a proper answer. Re. p. iii, lines 30-32. The authors should be complemented for their efforts to include views of the discount rate, such as those held by Schelling and Nordhaus, which are different than their own. However this summary gives short shrift to the "descriptive" approach. The implication of a trust fund earmarked for greenhouse victims seems extreme. The summary lacks discussion on sections 4.5 to 4.8.	IPIECA	18	A	
0	0	0	Overall this chapter is comprehensive, balanced and reasonably well written survey and evaluation of the available literature. Moreover, the chapter summary was in general a fair representation of the body of the text and was, in turn represented effectively in the PMS. Each of these aspects of the text should therefore be supported against any attempts to substantially amend them. The chapter summary and more importantly, the policymakers summary, does not adequately represent the treatment in the text of the alternative approaches to discounting, on the one hand, and the (affordable) safe minimum standards/natural capital approach on the other. This could be done and injected into the chapter on discount rates.	AUST	23	G	
0	0	0	There is a danger in assessing the impacts of climate change that assessors will consider the issue as but one other "project" and rely on existing literature about	CAN	24	G	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			discount rates and their optimal levels. The problem of climate change is a very long-term "project" and as stated in this chapter discounting is one of the critical issues in assessing its costs.				
0	0	0	This chapter seems rather esoteric and much of it is unintelligible.	CAN	24	G	
0	0	0	Re. p. ii, lines 32-34. The intergenerational equity questions are profound. GHG stabilization objectives may require substantial abatement by some of the world's poorest countries. Some of the benefit of these abatements will accrue to the wealthy. Vulnerability to climate change may be the greatest in the poorer countries. Questions about how to share the costs of abatement and distribute climate change damages are no easier to resolve than those regarding intertemporal questions. This should be handled by a clearer sense of the relationship between chapters 3 and 4.	USA	32	G	
0	0	0	Re. p. iii, lines 28-32. The authors argue that the proceeds of market investments are not likely to be set aside to compensate those adversely affected by climate change. The implication is that market rates of interest, or opportunity cost of capital, are inappropriate for discounting future benefits of climate investments. The argument is not convincing. While investment proceeds are unlikely to be set aside directly for the exclusive use of climate change victims, market investments will benefit individuals in the future, even the distant future. The opportunity cost of climate investments include foregone investments that would augment human and physical capital. Augmentations to the stock of human and physical capital will expand capacity to produce consumption goods in the future, thereby benefiting future generations. In fact, the industrial age has witnessed an extraordinary increase in wealth and living standards as one generation inherits capital from the previous generatin and leaves a larger stock of capital to the next generation. Also note that, although little physical capital from the dawn of the industrial age has survived to the present, no one can doubt that investments made at that time yielded benefits that still enrich us today, two centuries later. These benefits accrue to us today even though no one thought to earmark and reserve them for the end of the 20th century. Given the history of the creation of wealth over the past 200yrs, it is puzzling that the authors dismiss the possibility of adding to the wealth of future generations through investment in any projects but those that mitigate climate change. If this hypothesized inability to benefit the future by current investment is the sole argument against use of the opportunity cost of capital as the discount rate, then this criticism does not seem to	USA	32	G	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			be fatal. Use of the opportunity cost of capital as the discount rate would seem to be a defensible position. The chapter, which gives far too little attention to the opportunity cost of capital approach should be revised to correct this deficiency. However, we should be careful when thinking about our assumptions regarding the motives of past generations and their sense of moral obligation to us.				
0	0	0	Re. p. iii, lines 30-32. The authors should be complemented for their effort to include views of the discount rate, such as those held by Schelling and Nordhaus, which are different than their own. However, this summary gives rather short shrift to the "descriptive" approach. In particular, the implication that society needs to set funds aside, as in a trust fund, earmarked for eventual compensation of greenhouse victims seems extreme. So long as funds are invested productively, they will be available to future generations. Incremental economic growth provides the resources for future compensation for future victims. Compensation is really a redistribution problem for future generations, which can not and should not be solved now.	USA	32	G	
0	0	0	Page ii Summary, Lines 3-7 The recognition that this is a philosophical and ethical question as well as an economic one is appropriate and important. However, this also means that there is a range of advice based on different prescriptive and descriptive considerations. To communicate to policy makers the necessary absence of a definitive answer to this question is important in assessment of economic knowledge as applied to the climate change question.	USA	32	G	
0	0	0	Page ii line 20 How accepted is the Brown-Weiss argument? My sense is that it is not supported by any treaty. Rather it is more an ethical norm. Does terming it an international legal principle give it more weight than other philosophical criteria (eg. Rawls' difference principle or Nozick's theory of rights)?	USA	32	G	
0	0	0	COLLATED COMMENTS IPCC WORKING GROUP II DRAFT ASSESSMENT Chapter 4: Intertemporal Equity and Discounting Lead Reviewer's Overall Summary and Comments for Review Process:	USA	32	G	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			The chapter lays out the central issues of the longstanding discounting debate in economics somewhat independently from the specific program of global climatic changes (GCC). What connections there are to GCC are made strictly from the view of largely deductive economic theories. The chapter attempts to distinguish a "prescriptive" and "descriptive" as a way of introducing a more inductive approach but then seems to reject this view on "ethical" reasons. This is somewhat surprising, since the ethical arguments mentioned are more a matter of practicalities (ensuring future transfers) than they are a genuine consideration of moral obligations (e.g., stewardship). Of central concern is whether or not the chapter conveys to policy makers what they need to know to make informed choices regarding the discount rate for policy analysis in GCC. I think there are several serious problems here: I. The chapter fails to consider the more fundamental issue of the nature of the problem. As one reviewer points out, the authors proceed as if all the consequences can be framed as a gradual process of incremental damage. Under these conditions, the problem collapses to a debate over rates that may be of great interest to economists, but I believe will be regarded by policy makers as missing the point. In contrast, another reviewer faults the chapter for treating GCC as a special case. While I am inclined to believe it is, for a number of natural and social scientific reasons, I agree that the authors have not made the case here. The chapter should begin with a clear essay on why GCC is or is not different from any other policy concern. For example, the chapter states that future generations can be compensated for "some" environmental/natural resource effects, but what about the "and not for others" case? This should be followed by a discussion of the significant views of "better off" that would be at the core of alternative normative perspectives for this problem if we were to treat it as a special case. The relationships between Chapter 3 and this chapter should be clarified. II. The economic perspective should receive special attention, but the authors should carefully delineate normative and positive results. Policy makers will want to know when prescriptions are based on normative models (some of questionable empirical validity), and when they are based on credible scientific evidence. The chapter's distinction between "prescriptive" and "descriptive" approaches is misleading. In fact, both approaches are prescriptive; however, one is based on a largely deductive methodology while the other is more inductive. Both approaches are often at odds with empirical results in decision making and market behavior in the case of unfamiliar or poorly defined goods (and these major results should be made clear for policy				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			makers). What the authors present as an "emerging consensus" regarding discounting is clearly not one, given the reactions of the reviewers. III. Very little discussion is devoted to the implications for policy analysis in the real world. As examples, the chapter does not offer insights for sensitivity analysis, scenario development, or alternative treatments of the problem as might follow from specific stabilization policies. Contrary to the tone in the SUMMARY which endorses cost-effectiveness analysis (but not cost-benefit analysis) and a variety of ethical principles for addressing equity, the tone in this chapter emphasizes finding the "correct" rate of discount to decide about alternative policies. The chapter seems determined to make a single recommendation, rather than explicating reasonable alternatives that reflect different normative commitments and preferences. In addition, the chapter should more carefully distinguish the interesting cases of this problem: policy choice, project choice given a policy goal, catastrophic risks, and cooperative and non-cooperative policy strategies. IV. Key concepts and examples need clarification and editing. Some examples are confusing, key concepts are introduced with little definition, abstract methodological concerns are raised but not explained, and, as currently written, the annex does little to resolve concerns about the normative perspective or its empirical grounding. To help the authors think about revisions, I have organized all of the general comments under the four categories discussed above. In some cases, I have appended to a comment from a reviewer some additional concerns of my own. The specific comments are ordered by page and line number, but the category concerns are noted there as well. General Comments on Chapter from Reviewers: I. Intertemporal Equity 1. The Inappropriateness of Discounting A. Assuring Climate Change. Since the costs of averting change occur in the present, and the benefits in the perhaps distant future, discounting dramatically devalues the future values associated with it. Ironically, if we assume a smooth warming path with slowly accumulating net damage (as these authors do for the most part) then the adoption of this framework alone constitutes the decision to do nothing. There is no need for any analysis within it. This assures that the goal stated in the "Summary for				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			Policy Makers" of "stabilization of greenhouse gas concentrations" will never be met. The conclusion is such a short inference away from, and so completely determined by, the (unjustified) assumptions of the method that the whole thing seems silly. B. Immortal Agents. The authors are quite mistaken to brush aside Tom Schelling's criticism that long term discounting assumes an immortal agent. Surely Schelling is right that there is a world of difference in thinking about my own future consumption and that of others. This difference causes the whole framework used by this chapter to collapse. The authors have conflated issues of allocation with those of distribution. This is completely illegitimate. C. Time and its Correlates. Further still, the idea of discounting is far more problematical than normally assumed by these authors. As Derek Parfit has argued, discounting typically confuses things that are correlated with time, with time itself. A variety of arguments are offered in support of discounting: risk, opportunity costs, the supposition that future generations will be better off than we are, etc. But in none of these cases, is it time itself that is the key issue. These authors exhibit these confusions in numerous places including pages 9,11 and 17. D. Time Preference. We would think much more clearly about the future if we used a disaggregated vocabulary rather than starting with the assumption the there is a social discount rate. I think that there are also reasons to doubt that individuals have a rate of time preference; or at least, that it functions in the broad way that economists assume. For example, why must present and future time value be related by an exponential function? Why not some other relationship? What is referred to as time preference needs to be disaggregated in much the same way as "the" social discount rate. See, for example, Rawls' discussion of this subject in A Theory of Justice. 2. Problems with the Point of Departure A. Distributing Utility. The authors are quite mistaken in thinking that the issue is the distribution of utility. Utilitarianism has been virtually universally rejected by philosophers, but the authors seem unaware of this literature. Their statement (page four) that their approach derives from a "persuasive axiomatic structure" hovers somewhere between irrelevant and outrageous. They seem uninterested in the questions of whether the system is true or not. Who cares if it is axiomatic or not. The utilitarian project has failed utterly to offer a satisfactory account of moral obligation.				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country	#)		
			- Utilitarians have been unable to show how to get from the (I believe false) proposition that everyone seeks to maximize their own utility, to the idea that we have a moral duty to maximize the utility of everyone. - In offering no place for the language of rights (Bentham referred to rights as "nonsense, nonsense on stilts") it authorizes the ruthless exploitation of the minority if we can show a net gain of utility. - It is infeasible from a motivational point of view in the classical version (greatest happiness of the greatest number) because it requires more altruism than we can reasonably expect people to muster. (Further, it is mathematically impossible to maximize two variables.) The self-interested motivational assumption of the neoclassical school fails for the opposite reason in that it fails to offer any account whatsoever of what we owe one another. The attempts on the part of modern economics to distance itself from the failure by dropping the language of utility in favor of that of preferences backfires. If preferences are not connected to utility then it is completely mysterious why one should care about them. Incidentally, a utilitarian should consider the preferences of at least some nonhuman animals since many of them can also experience pleasure and pain. B. Finding a Foundation. Not all goods are, or should be, tradable at the margin. Coase type transactions cannot go all the way down--otherwise we would have to bribe people not to assault us. The way all societies actually function is to block a set of exchanges and then allow Pareto transfers above those constraints. In our society, for example, votes cannot be legally marketed, nor can certain fiduciary goods like national battlefields. C/B analysis sheds no light on which exchanges should be blocked. One might reasonably assume that exchanges that impair the earth's life support systems should be blocked as we have done in the case of ozone depleting chemicals. 3. An alternative point of departure: Trusteeship The authors seem to misunderstand the trust model (p. 3) in that they imply that it allows for perfect substitution. Here they conflate technical with moral substitutability. The conventional efficiency/equity distinction is dysfunctional because it misunderstands the nature of goods. A. Problems with the Efficiency/Equity Distinction. In the standard view there are two				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			objectives for policy: efficiency, to be achieved by corrected markets; and equity which is usually not very robust- but is either a constraint on efficiency or is some ways to be traded off against it. There are a number of problems which go way beyond the one normally recognized: that economics doesn't have much to say about equity. First, the basic distinction does not parse at the joints. The idea is that there are goods traded in corrected markets that yield efficiency makes it sound as if there is only one or two kinds of goods. But Walzer is certainly correct in Spheres of Justice in his observation that goods move in accordance with their meanings as much as with their prices. There are at least four different classes of goods in all societies: 1) those traded in markets; 2)those distributed according to merit--public office, licenses to practice medicine and the like; 3) those distributed according to need--e.g. food stamps; and 4) fiduciary goods which one generation preserves for those who follow. (My argument is that because of its role in the preservation of species and cultures that climate is a good of this kind.) Seen from this perspective the role of public policy is the proper maintenance of these various spheres--not the maximization of utility or consumption in one of them--the market. Market Preconditions. Once we distinguish between markets and their preconditions the question arises of how should we think about those preconditions. In Restoring the Public Trust I argue that a fiduciary model captures what is at stake with respect to climate change. This grounds, I believe, an obligation to leave the world at least as good as we found it--meaning leaving its productivity and diversity intact. Because of the role of climate change in species extinction, and as a possible threat to some of world agriculture, I argue that there is an obligation to stabilize climate. Seen from this point of view the role of economic analysis is to be concerned with discovering the most cost effective means of reaching the goal of having GHG emissions and sinks in rough equilibrium. A. Tractable Morality. There is no obligation to maximize utility or preference satisfaction or anything in that family of ideas. We have a much more tractable account of our moral obligations. Rather, we can follow Locke in stating our obligations in terms of the preservation of persons: understanding this to mean preserving their lives from external threats, preserving and enhancing their moral and religious choices, and assuring the means to subsistence. In the trustee conception the fundamental job of the nation states is not to create opulence or to correct for market failures--but to preserve the persons of their citizens				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			now and in the future. An element in this overall obligation is to keep the various kinds of goods discussed above in proper balance. Other Problems. This chapter also fails to draw on the large literature on intergenerational justice. An excellent compendium by Bayard Catron entitled Ethical Dimensions of Environmental Policy and Decision Making: Risk Management, Intergenerational Equity, and Discounting(Washington, D.C.: NAPA, 1993) would have helped a lot. Beyond this the authors seems unaware of the literature on the nature and unpredictability of ecological change. See, for instance, C.S. Hollings, "A Cross-Scale Morphology, Geometry, and Dynamics of Ecosystems in Ecological Monographs 62(4) 1992, pp. 447-502, esp. pp. 478-485 for a discussion of the inherent unpredictability of the future. 4. Social welfare functions are generally assumed to be an summary of the preferences revealed by a political process, and are used as a convenience in theoretical explorations of the necessary conditions for maximizing some concept of social welfare in which both efficiency and equity matter. When a policy that satisfies the efficiency conditions results in a redistribution of income that is judged to be undesirable (based on some idea of a social welfare function) the consensus approach is to design compensatory programs or transfers that make it possible to achieve both efficiency and equity. This is the Birdsall and Steer recommendation. The "prescriptive" approach abandons any efforts to reconcile efficiency and equity, and recommends policies that leave all generations worse off compared to the welfare they could achieve if efficient climate policies were adopted and intergenerational transfers dealt with through policies affecting savings and investment. Birdsall, N. and Steer, A. Act Now on Global Warming - But Don't Cook the Books, Finance and Development 30 (1), pp. 6-8. 5. The discussion of the chapter on the problem of earmarking revenues for future generations in a Fund for Greenhouse Victims (Page 16, lines 33-35) is both erroneous and irrelevant if the possibility of providing for future generations through capital investment is admitted (Stiglitz). Today's investment in physical capital increases future productive capacity; no other funding is required to make future generations better off. Stiglitz, J. E. The Rate of Discount for Cost-Benefit Analysis and the Theory of the Second Best in R. Lind ed. Discounting for Time and Risk in Energy Policy. Resources for the Future, 1982.				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			6. I have a serious interest in this issue, and found Chapter 4 to be helpful to my own thinking. However, I feel the chapter overstates the merits of the prescriptive approach relative to the merits of the descriptive approach. My comments below elaborate on this point, and suggest some textual changes that would help to redress the balance. The primary criticism leveled at the descriptive approach is that there is no guarantee that investments we make now will ultimately benefit individuals in future generations who may be harmed by climate change. However, this exaggerates the difficulties of transferring non-environmental capital to those harmed by climate change, and it fails to recognize the difficulties inherent in transferring environmental capital. Barring an event like the "dark ages," investments which expand the stock of technological knowledge cannot easily be squandered by future generations. Moreover, since the benefits of advancing technology are significantly a public good, it is not plausible that these benefits will somehow fail to help the particular individuals in future generations who may be most harmed by climate change. Likewise, investments in education, particularly of women, seem to produce self-sustaining social change which lowers population pressure, and this too has spillover benefits to all members of future generations. Thus some very important classes of non-environmental investments are likely to have enduring payoffs in future generations, and those payoffs are likely to be available to those who are ultimately harmed by climate change. Moreover, it should be acknowledged that environmental investments we make to reduce CO2 emissions can be subverted in the future, as long as oil, gas, and coal resources remain available to be used at some future date. Thus today's investment in CO2 emissions reduction may be equally or more at risk of being squandered or "misappropriated" than investment in other kinds of non-environmental capital, particularly education and research. 7. As Chapter 4 acknowledges, the prescriptive approach is fundamentally an ethical position, shared (more or less) by many social scientists who are highly educated and wealthy, at least relative to the people likely to bear the cost of controlling CO2. If the observed income redistribution policies of the world's governments are grossly inconsistent with the ethical norms of these individuals, it seems to me that the common sense explanation is that most of humanity does not share these ethical norms. The chapter acknowledges that this is possible, but the point is "soft-pedaled," particularly in the summary section where it is not mentioned (even though the critique of the descriptive approach is prominently featured there.)				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			According to Aaron et al. (1994), these values are affected by affluence. Our future generations, if wealthier and better educated, can be expected to place more value on "respecting and preserving nature and the natural." Will this be handled in the estimates of avoided damages? Aaron, H.J., Mann, T.E., and Taylor, T (eds), 1994, Values and Public Policy, The Brookings Institution. 8. It seems to me much more work needs to be done on telling the modelers how to design their models so as to answer the questions that are imbedded in the discount rate issue. To the extent that the present is transferring substantial resources to the future, we ought to be able to tell people how much. To the extent that under reasonable assumptions per capita consumption will be greater in the future, again, we should know much greater. In other words we shouldn't bury major ethical decisions in the discount rate. In part, this is a result of the lack of connection between Chapter 3 and 4. If the authors want to set aside the major ethical issues then they should explain how decision rules from Chapter 3 will interact with the approaches in Chapter 4. 9. One reason for this is that the preferences of today as expressed by democratic governments, as Chapter 4 notes, differs drastically from the consensus of economists as moral philosophers. We need to give the democratically elected decision makers the information needed to make these decisions, not bury the decision in the choice of a discount rate which reflects our moral judgments which are not those of the public. If we don't do this, our work will become more and more irrelevant. II. Economic Efficiency and Discounting 1. The chapter is unbalanced in its presentation of the economic theory relevant to choice of discount rates. It is not the consensus of professional economists that the social discount rate should be based on the kind of ethical judgments used in the "prescriptive approach" to justify a discount rate of 3% or less. What the chapter labels the "descriptive approach" is in fact the mainstream approach to the subject. The chapter should concentrate on the descriptive approach, and give the prescriptive approach only brief mention as a perspective that suggests climate policy should be treated as a special case and based on ethical judgments that have not been embodied in any other economic policy.				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			2. The chapter fails to provide a justification for choice of a discount rate lower than the before tax return to capital. What Stiglitz, Dreze and Sandmo, Arrow and Kurz and others demonstrate is that when governments cannot use either optimal taxes or make lump-sum intergenerational transfers, the correct discount rate for evaluating public investments may not equal the before-tax return to capital. There are necessary conditions for welfare maximization that must hold among the return to capital, before and after tax rates of return, and the social discount rate. The chapter states correctly (Page 13, Line 2) that with nondistorting taxes and optimal intergenerational transfers, the social discount rate will equal the before tax return to capital. The chapter is incorrect in dismissing this as a special case. These assumptions are the normal starting point for applied welfare economics. The burden of proof should be on those who argue for different assumptions. Moreover, as will be discussed below, alternative assumptions do not lead to any simple characterization of the social discount rate. 3. If existing taxes create significant distortions between the before and after tax returns to investment, a case can be made for choosing a discount rate between the two (as Nordhaus and others suggest) or for converting foregone investment to consumption at the before-tax return to capital. These are necessary conditions for intertemporal efficiency, and hold regardless of the choice of a social welfare function. Choosing the weights to be applied to before- and after-tax rates of return in computing the average requires an explicit analysis of how climate policy affects investment and consumption. The chapter includes no such analysis and therefore has no basis for concluding that the correct discount rate is not the before tax return to capital, as it would be if the costs of climate policy all come from investment. Nordhaus, W. D. Managing the Global Commons: the Economics of Climate Change. MIT Press, 1994. 4. It is only if governments cannot make intergenerational transfers that choosing a social discount rate different from some weighted average of before and after tax rates of return to capital can be desirable (Stiglitz). But this does not justify an analysis that constructs a social rate of discount from ethical principles, as the prescriptive approach recommends. Instead, the correct theoretical approach (Stiglitz, Arrow and Kurz) is to model explicitly the constraints presumed to exist on intergenerational transfers, the characteristics of the investment in question, and the relation between climate policy, consumption and investment. As Stiglitz shows, the conclusions that follow about the relation between the social rate of discount and returns to capital (before or after tax) will depend on all these factors, and the social rate of discount may be higher or lower than the before tax return to capital. The conclusions that the chapter reaches on the				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			range of discount rates is not based on any such analysis, and therefore has no foundation. Stiglitz, J. E. The Rate of Discount for Cost-Benefit Analysis and the Theory of the Second Best in R. Lind ed. Discounting for Time and Risk in Energy Policy. Resources for the Future, 1982. Arrow, K. J. and M. Kurz. Public Investment, the Rate of Return and Optimum Fiscal Policy. Johns Hopkins University Press, 1970. 5. All of the theory of social discount rates assumes that governments attempt to maximize a social welfare function, but face constraints on tax and transfer policy that make it necessary to choose a social discount rate different from the private return to capital. None of the economic theory of discount rates is based on the assumption that governments are maximizing the wrong social welfare function. This is the assumption on which the prescriptive approach adopts (Page 12, line 32). The prescriptive approach posits a social welfare function different from that which governments are assumed to be maximizing in making economic policy, and then uses it to argue for a low discount rate for climate policies. That entire line of reasoning is illegitimate, and certainly does not represent the consensus view of mainstream economists. 6. The "descriptive" approach, which assumes that the preferences revealed by current policies reflect the social welfare function of the nation in question, is the mainstream approach and should be presented as such. The complexities involved in choosing a discount rate for public investment with constraints on tax policy and distribution can then be discussed in that context. 7. The prescriptive approach is relatively well-explained. However, the descriptive view is not presented very coherently. It points to the relevance of alternative investment opportunities, but does not specify exactly what the discount rate should be. 8. The main area of omission in this chapter is the psychological work on intertemporal choice. This research shows a number of decision biases that may have policy implications. Below is a reference list of some potentially relevant papers. Benzion, U., Rapoport, A., and Yagil, J. (1989). Discount rates inferred from decisions: An experimental study. Management Science, 35, 270-284. Cairns, J.A. (1992). Health, wealth and time preference. Project Appraisal, 7, 31-40. Cropper, M.L., Ayded, S.K., Portney, P.R. (1994). Preferences for life saving				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			programs: How the public discounts time and age. <i>Journal of Risk and Uncertainty</i>, 8, 243-265. Ganiats, T.G. (1994). Discounting in cost-effectiveness research. <i>Medical Decision Making</i>, 14, 298-300. Keeler, E.G. & Cretin, S. (1983). Discounting of life-saving and other non-monetary effects. <i>Management Science</i>, 29, 300-306. Lipscomb, J. (1989). Time preferences for health in cost-effectiveness analysis. <i>Medical Care</i>, 27, s233-s253. Loewenstein, G. (1987). Anticipation and the valuation of delayed consumption. <i>Economic Journal</i>, 97, 666-684. Loewenstein, G. (1988). Frames of mind in intertemporal choice. <i>Management Science</i>, 34, 200-214. Loewenstein, G. & Prelec, D. (1992). Anomalies in intertemporal choice: Evidence and interpretation. <i>Quarterly Journal of Economics</i>, 107, 573-597. Loewenstein, G. & Thaler, R.H. (1989). Anomalies: Intertemporal choice. <i>Journal of Economic Perspectives</i>, 3, 181-193. Olsen, J.A. (1993). On what basis should health be discounted? <i>Journal of Health Economics</i>, 12, 39-53. Prelec, D. & Loewenstein, G. (1991). Decision making over time and under uncertainty: A common approach. <i>Management Science</i>, 37, 770-786. Redelmeier, D.A. & Heller, D.N. (1993). Time preferences in medical decision making and cost-effectiveness analysis. <i>Medical Decision Making</i>, 13, 212-217. Redelmeier, D.A., Heller, D.N., & Weinstein, M.C. (1994). Time preference in medical economics: Science or religion? <i>Medical Decision Making</i>, 14, 301-303. Shelley, M.K. (1993). Outcome signs, question frames, and discount rates. <i>Management Science</i>, 39, 806-815. Shelley, M.K. (1994). Gain/loss asymmetry in risky intertemporal choice. <i>Organizational Behavior and Human Decision Processes</i>, 59, 124-159. Thaler, R.H. (1981). Some empirical evidence on dynamic inconsistency. <i>Economic Letters</i>, 8, 201-207. An important issue to resolve for policy makers: How is it we can seriously challenge decision making for unfamiliar goods and not "choices?" In addition, what do these studies indicate about framing the "time horizon?" 9. This seems to me to be the next step in the process of creating the models and analysis that will help us perform a systematic economic analysis of climate change policies. 10. The chapter exhibits two strong biases of the authors: (1) the "proper" discount				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			rate is the social rate of time preference (SRTP) and (2) the component of the SRTP corresponding to the pure rate of time preference should be set equal to zero. These positions do not represent the consensus of the economics profession and the chapter should be revised to provide greater balance in the treatment of different approaches to discounting. 11. The formulation of the SRTP as the sum of the pure rate of time preference and an adjustment for changes in the marginal utility of consumption due to per capita consumption growth is presented as if this is a general result that is value free. It is described as "the fundamental equation for the discount rate of consumption," (page 6, line 44). This treatment obscures normative assumptions that underlie the derivation of the SRTP. For example, the derivation is dependent upon acceptance of assumptions about "welfarism," (the concept that social welfare is a function of only the welfare of individuals), the comparability of welfare across individuals, and a specific class of social welfare functions. The underlying social welfare function assumes that social welfare in time t is reducible to per capita consumption in time t and is independent of the distribution of consumption among individuals in time t. Individuals living in different periods enter the social welfare function identically with the exception of a discount factor for pure time preference that varies as a function of distance from the present. These normative assumptions yield a SRTP that varies with per capita consumption growth, adjusted by the marginal utility of consumption, but not, for example, changes in the variation of consumption across individuals. The assumptions may be reasonable approaches to simplifying the problem intertemporal optimization and discussion of them may not be necessary when writing for professional economists. But the audience of the WGIII report will include non-economists. For these readers, it is important to make the normative underpinnings of the SRTP explicit and discuss what they imply about intergenerational and intragenerational equity. 12. This chapter has improved over earlier versions, but still could use some work. One general suggestion would be to have the chapter consider efficiency on a level more comparable to the current emphasis on equity. For example, shouldn't efficiency be in the chapter title and receive more attention in the summary? Also, there could be some additional explicit discussion of what efficiency means in the intergenerational context; the standard view that efficiency is a less controversial criterion than equity				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			has some merit for this application. III. Implications for Policy Analysis 1. I believe that the Chapter is an excellent survey of the issues and literature on discounting and intergenerational equity. It falls short of giving the modelers who are trying to evaluate alternative policies any specific guidance. I suggest an approach to this shortcoming. I also feel too little has been said about sequential analysis of options and particularly the option of waiting. 2. However, if I were one of the two or three dozen researchers developing integrated assessment models, I probably would feel let down that I wasn't told which rate I should use in my model, or more importantly, how I might modify my model or use it to answer the questions regarding efficiency and intergenerational equity that are addressed in Chapter 4. 3. Let me suggest an approach, although time and space preclude a complete analysis of this issue which should be the next project for research on discounting and global climate change. I believe the key to the answer lies on the discussion on pp. 13-14. There are two key rates: (1) the rate at which we discount consumption and (2) the marginal rate of return on investments that are alternatives to investments in climate change abatement. I suggest that we keep these two rates separate in our models for the purpose of clarity. For example, in integrated models that explicitly model economic growth, one would use the rate of return on alternative investment in determining the growth path and consumption path if the proposed investment in climate change were instead invested in the economy. Consumption over time would then be discounted to its present value using a rate reflecting the SRTP. This would then become the baseline against which global climate policies would be compared. This seems to be what the chapter is suggesting, but it is somewhat hidden by all the other arguments. 4. This approach is very similar to the shadow price of capital approach, however, by disaggregating the analysis, it forces us to specify and debate what the alternatives to investment in climate control are and what rates of return could be earned. It forces us to look at consumption rather than GNP. We can debate and vary the SRTP of discount separately. In short, it helps us keep straight the myriad of issues that are involved and doesn't bury them in a single discount rate. For example, Cline gets a discount rate of 2% - 3% (p. 14) by assuming that 80% of				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			cost comes at the expense of consumption and 20% at the expense of investment. Such an assumption might have followed from the assumption that the money was raised by taxation and the marginal propensity to consume was .8. The problem with this analysis is that the government could have invested it in other public projects. The problem with most second-best lines of analysis is that we don't properly account for the opportunity cost and the approach suggested above would force us to do that. 5. Finally, we need to look more carefully at sequential approaches to this problem. The sequence we should follow is not necessarily act, learn, act. The optimal sequence, given the uncertainty we act may be to wait, learn, wait, learn, maybe act. Given the feasible size of budgets that will be devoted to this problem, gathering information and developing the technologies for the future may be our best option. 6. Economists know something about how individuals and companies trade off current and future cash or consumption. We know much less about how people trade off their consumption for the consumption of their descendants -- or don't like the answer we observe in such behaviors as national finances. We have even less to say about how people trade off their consumption relative to the consumption of future generations in other countries -- or don't like the answer at all, as demonstrated by the abhorrence of the American electorate for foreign aid. Can this meaningfully be expressed as a discounting problem at all? Schelling's argument that after a certain point future generations run together has some real common sense to it. Furthermore, much of the benefit that takes place far in the future cannot reasonably be estimated anyway, because it involves health and eco-system effects which are not well-defined and whose valuation is uncertain and controversial. This suggests that a multi-criteria approach to the problem is more suitable. However, this risks painting the problem as one of fundamental values of current generations about their stewardship responsibility over the planet and its future inhabitants, and thus losing the sense that these are small benefits far in the future. 7. These are topics of greater than average difficulty. Consideration should be given to organizing the chapter along the following lines: - Economics provides no clear answers to many of the issues raised by discounting in this situation. There are strongly held opinions on all sides of the question. - The use of multi-criteria analysis provides an alternative to trying to discount the future benefits of current climate change mitigation strategies, although multi-criteria analysis is not without its own drawbacks.				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			- There is a strong philosophical following for the use of low social discount rates for discounting future consumption, and a strong practical following for the use of rates nearer market levels. Trying to value the effects of foregone investment on future consumption is complex and possibly subject to manipulation. It is hard to justify lower discount rates for this particular type of social investment than for the many other types of investment that are currently made. Faced with this dilemma, some analysts have chosen compromise rates between these positions. An alternative is the use of multiple discount rates by analysts. The implications of this approach, with all results provided to other analysts and policy makers, might usefully be addressed in this chapter. 8. Firms and Planets. The authors conflate the use of a perfectly usable framework about decisions within a firm or public agency with a program of planetary management. We need to distinguish between the means to achieve efficiency through markets or their surrogates, and the things that make markets possible--their preconditions. In "The Cultural Contradictions of Capitalism" Daniel Bell argues convincingly, to me at least, that capitalism depends on certain virtues (e.g. thrift, hard work etc.) that it tends to erode. Surely the earth's basic systems such as climate are candidates for being among market preconditions, and are being disequilibrated by unconstrained markets. 9. GNP a Mismeasure of Man. The problems with the GNP (p. 21) measure are far more extensive than even the literature on its defects (e.g., corrections for capital depletion, defensive expenditures and the like) recognizes. None of these revisions deals with the underlying problem that it embodies far too narrow a conception of human well-being to begin with, because it focuses too much on consumption. A much more promising way of thinking is being developed by Nussbaum and Sen entitled the capability approach. see, for instance, The Quality of Life. They argue that there a generic set of capabilities that define the good life, and that consumption is instrumental to only some of them. This grounds Sen's claim that development as normally understood is a result of conceptual and moral failures. IV. Editing and Clarification All but one of these points are noted in the specific comments on the chapter. 1. My comments will likely point out which parts of this chapter are unclear to a				

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			non-economist. This chapter sometimes provided clear explanations of relevant concepts and other times used cryptic economics shorthand that I was not able to follow				
1	1	14	Why is the alternative chapter posited? If efficiency is an important consideration in discounting - and surely it is - then it should be mentioned in the actual title and should get adequate treatment in the chapter.	USA	32	G	
1	2	24-26	Agreement on this is not widespread.	NED	09	G	
1	2	33-34	Literature on the growth of green GNP (Repetto, Huetling) sometimes comes up with growth rates over the past decades of -0.5 to -3%.	NED	09	G	
1	2	10-11	THE choice of words "collapse of future" could have a wide range of interpretation depending upon a readers frame of reference. Suggest text read instead: Such results make clear how difficult it is to draw quantitative conclusions from calculations based on such long time horizons.	IPIECA	18	A	
1	2	7-11	The reviewers find that the example given here is very effective in driving home the importance of discount rates in the context of climate change. We would encourage the use of more examples of this type in this chapter.	CAN	24	G	
1	2	11	The flip side of the collapse of future values due to discounting is that very small displaced investments can lead to very large future shortfalls in output.	USA	32	G	
1	2	28-34	This generalized egalitarianism seems to have to do with transferring wealth from the rich to the poor (utilitarianism) and seems logically unrelated to intertemporal or intergenerational trade-offs. It just so happens that future generations are expected to be wealthier than the present generation. Doesn't this assumption need to be considered in constructing our scenarios of the future?	USA	32	G	
1	2	38	The implication that markets do not effectively allocate goods over time (and particularly over generations) is controversial. It affects more than global warming policy and raises significant questions about national savings policy and use of exhaustible resources. Do not believe there is a consensus among economists that market interest rates are generally incorrect guides to behaviours in those settings.	USA	32	G	
1	2	40-44	How, exactly, are intergenerational trade-offs for environmental goods different from those for private consumption goods? Converting environmental goods to their	USA	32	G	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			equivalent in private consumption goods would seem to ensure that these two types of trade off are treated equivalently, not differently.				
1	3	9-11	The reviewers agree with this point.	CAN	24	G	
1	3	8	What is the "incremental component" of the discount rate? Is this the idea that risks compound over time? If so, why would we not want this aspect incorporated into the discount rate?	USA	32	G	
1	3	13	How can certainty equivalents be used to treat issues of equity?	USA	32	G	
2	3	42	It is argued that most countries pass the weak sustainability criteria . Believes that this conclusion is based on Pearce's compilation of estimates a couple of years ago. These estimates are highly uncertain, inherently complex and difficult.	SWED	17	G	
2	3	35	The sustainability school of thought as outlined by: Pearce, D.W. and R.K. Turner (1990), Economics of Natural Resources and the Environment, Harvester Wheatsheaf, London, is an important published school of thought in respect of intergenerational equity and could be added to the text. Add: The extent to which natural and cultural resources are substitutable is critical to this analysis and is highly contentious. Many economists including Pearce and Turner (1990) stress the need for sustainability limits to guide natural resource use which will be needed by, but cannot be created by, future generations.	AUST	23	G	
2	3	37-41	Good point.	CAN	24	G	
2	3	21	The compensation problem deserves some discussion, it is relevant for any discount rate.	USA	32	G	
2	3	33	Why "must" discussions of intergenerational equity go beyond sustainability? Brown-Weiss, for example, implies that sustainability is a "legal" (though perhaps more accurately, "a plausible ethical") obligation that generations face. What evidence is there of a consensus that governments should be allowed to make poorer generations suffer so long as richer generations gain sufficiently? Arguably this view is controversial, yet it is implicit in the utilitarian framework that drives the equity analysis of this chapter. While this framework is important and merits exploring, it should be made clear that this is not the only possible framework. It should also be explained to policy makers that despite the technical content of this discussion, the material covered is quite normative, and that while economists have expertise in	USA	32	G	

Reference			Comments	Reviewer (Country #)		ID	Response
Section	Page	Line					
			analyzing these norms, they are not in a position to determine them for society.				
2	4	14	According to Chapter 3, Rawls is a utilitarian.	NED	09	G	
2	4	0	It should be noted that Rawls himself argues that the maximum criterion should not be applied to intergenerational problems (Rawls 1991).	SWED	17	G	
2	4	10-19	Contrast between utilitarianism and min-max is well summarized.	USA	32	G	
2	4	21-35	Re. Schelling's dissenting opinion. Distributional considerations can be incorporated into utilitarianism. Distributions affect individual utility by way of perceptions of fairness and emotions such as envy. (see also p. 5, lines 9-18).	USA	32	G	
2	4	0	Re. Box. The discussion of Schelling's view is too abstract to be useful to policy makers. Regarding the conclusion in the Box, it is not obvious that the analyses presented in the chapter-- which, in effect, suggests consumption transfers across generations to help equate marginal utility -- is appropriate in a world where richer nations make only modest transfers to poorer ones.	USA	32	G	
2	5	12	The sentence on Thurow's paper should probably be moved to later in the para.	USA	32	G	
2	5	20-26	If environmental outcomes are not discounted, but other outcomes (eg, financial ones) are, certain inconsistencies will result such as preference reversals (see Keeler and Cretin, 1983). This is certainly a consequence of "special treatment" that should be pointed out to policy makers.	USA	32	G	
3	0	0	The following comments are applicable to Chap. 4, sections 3.3.1 and 3.7, chap. 6, sections 6.1.2 and 6.1.3, and p. 7 of the PMS. The use of discount rates assume that investment is made at time "t" and the yield would come sometime in the future. It applies to marketable goods and services. The choice of discount rates may be extremely difficult in addressing environmental goods and services. This is true, particularly, to non-marketable goods and services. Non-marketable goods and services may represent secondary, tertiary, etc., indirect or derived costs and benefits of economic activities. In fact, ecologists have argued that that the environmental value of non-marketable goods and services may represent the largest portion of environmental damages, more so of their cumulative effects. It is	CAN	24	G	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			suggested in the report that the relative prices of environmental services is unlikely to rise and thus the effective discount rate can be lower than discount rates used for goods (marketable?). This is particularly troubling issue. Considering the fact that there are limited information on ecological effects of GHGs, and the need to account (value) for non-marketable goods and services, the assumption of declining/constant price or discount rates is questionable.				
3	5	30	The discussion in the prior section is also prescriptive.	USA	32	G	
3	5	37-44	See comment re line 30. Would not the answer to these three questions be the same, because of the inconsistencies that result from using different discount rates for different outcomes?	USA	32	G	
3	6	0	The five points put forward here are clearly stated and well argued.	USA	32	G	
3	6	7-10	Why is this argument limited to benefits accruing to the same generation? The whole idea of utilitarianism is that utility can be traded off across people.	USA	32	G	
3	6	38	Should add the following sentence to this para,: "However, given appropriate estimates of relative prices, there is no reason to explicitly modify the discount rate."	USA	32	G	
3	7	0	The reviewer has doubts on whether the formula is correct. Seems to be too simple. It presumes that welfare is so well-defined that one could take the first derivative to consumption. This is doubtful at least, as it is doubtful that, could it be done, "v" would be a constant as is suggested. But if it could be done, why would one be happy with the first order Taylor approximation? Global change is hardly a local problem.	NED	09	G	
3	7	20-24	"If the project displaces private investment that has a high marginal productivity...The prescriptive view takes into account opportunity costs in calculating changes in consumption, but in valuing the changes in consumption, uses the SRTP." It appears that what is being said is that, where mitigation projects displace other investments, future consumption must be reduced by the consumption that the displaced investment projects would have generated. It is net consumption that is to be discounted with the social rate of time preference. This appears to be a compromise between using low social discount rates throughout the analysis and using the opportunity cost of capital throughout the analysis. It is not clear however, what one does in practice. The suggested discounting method is both confusing and subject to manipulation. Specific examples are required to aid clarification.	IPIECA	18	A	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
3	7	3	The social welfare function and related relationships used to derive this equation should be stated explicitly. It is the most important equation in the chapter but has not clearly been derived for readers. A reference to the annex and a full presentation there would be useful.	USA	32	G	
3	7	8-14	Throughout the chapter it is unclear about the relationship between the SRTP and the market interest rate. Is SRTP meant to express discounting above and beyond discounting because of investment opportunities? Investment opportunities (leading to a particular market interest rate) presumably exist because of economic growth, g. So why is g so much smaller than current interest rates? (see also p. 12, line 38 to page 13, line 8.)	USA	32	G	
3	7	20-24	"If the project displaces private investment that has a high marginal productivity... The prescriptive view takes into account opportunity costs in calculating changes in consumption, but in valuing the changes in consumption, uses the SRTP." Believe what is being said here is that, where mitigation projects displace other investment, future consumption must be reduced by the consumption that the displaced investment projects would have generated. It is net consumption that is to be discounted with the SRTP. This appears to be a compromise between using low social discount rates throughout the analysis and using the opportunity cost of capital throughout the analysis. However it is not clear what one does in practice, and am concerned that the discounting method suggested will be both confusing and subject to manipulation. Any investment can be argued to displace some other investment that would generate (at least) the opportunity cost of capital. And that investment will yield returns, some of which will be re-invested. The suggested procedure may be better in concept than in practice. If this procedure is to be proposed, specific examples are required for clarification.	USA	32	G	
3	7	44	This is the only reference to Loewenstein and others on decision biases in intertemporal choice. In addition to the common difference effect cited here (lower discount rates for longer delays), descriptively, discount rates are lower for large magnitudes, for losses compared to gains, and for sequences over outcomes, compared to individual outcomes. Finally, temporal discount rates expressed in decision-making experiments are typically 50% annually or more, much higher than those discussed in this chapter. What implications to these findings have for potential climate change policies and the success of their implementation? One implication might be that because many people have personal discount rates much higher than those suggested in this chapter, they would be uncooperative with the resulting policies. Am not familiar	USA	32	G	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country	#)		
			with psychological work looking at intergenerational decisions however (but see Lipscomb, 1989).				
3	8	0	As stated elsewhere in this chapter, should'nt risks, such as the small change of human extinction, be incorporated into a certainty equivalent, which would then be discounted?	USA	32	G	
3	9	19	The finding that the optimization problem is not well defined should be further elaborated.	USA	32	G	
3	9	24-35	It is not clear why these knife-edge results occur.	USA	32	G	
3	10	9	Do not share the opinion that it be viewed as a "problem" with utilitarianism. The normative status of utilitarianism is independent of descriptive behaviour(such as the unwillingness of people to make large sacrifices to benefit future generations.)	USA	32	G	
3	10	38-41	This is biased. If one discounts outcomes from generation 1 to generation 2 much more than for generation 101 to generation 102, one is not exhibiting constant discounting. Although someone in generation 1 may view a benefit delivered to generation 101 as equivalent to the same benefit to generation 102, someone in generation 101 would not have the same view. This illustrates the preference reversals that result from non-constant discounting. The comment about the emphathetic distance suggests the need to clarify how the discounting is grounded in a particular time period. Also, other social science research shows that there are markedly different cultural views on concepts of time that affect behaviour.	USA	32	G	
3	11	22	Insert "absolute value of" before "elasticity".	USA	32	G	
3	11	26	Are the low rates of productivity a US phenomenon or applicable to the world?	USA	32	G	
3	11	38	See this reviewers comment for p. 11, line 22.	USA	32	G	
3	12	11-12	This statement does not seem right. A very high theta (say 50) would imply that one requires an incredibly high rise in the next generation's per capita consumption before one would agree to a small decrease in one's own generations's consumption - not very equitable. Instead higher values of theta seem to imply more selfishness, lower values imply altruism, and some intermediate values imply equity.	USA	32	G	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
3	12	11	What is meant by "The more weight equity." there are all kinds of equity criteria, each with different values of Q. One view of equity would be very protective of worse off generations; another might be less so.	USA	32	G	
3	12	27	While there are a number of equity reasons to intervene to help the very poor, the idea that government should fine tune the income distribution is less clear. At some point government intervention can cause inefficiencies and can run into other equity problems such as those associated with confiscation.	USA	32	G	
3	12	40	Should "even" be "particularly"?	USA	32	G	
3	13	12-17	Where do these specific discount rates come from?	USA	32	G	
3	31	0	Needs further elaboration.	NED	09	G	
4	14	13	Should'nt one state that based on "certain" ethical grounds, it is tough to support the higher time preference rate?	USA	32	G	
4	14	15	What is OECD?	USA	32	G	
4	15	30	Replace "most plausible discount rates" with "discount rates below 10 per cent". The presentation of the example does not follow the methods advocated by the chapter. The authors should carefully constuct an example that demonstrates the various discounting approaches discussed in the chapter, including all their steps.	USA	32	G	
4	15-16	0	The meaning of "institutionally infeasible" is not apparent as cited in reference to option d. An explanation needs to be provided.(p. 15) Re. p. 16, lines 43-44. The prescriptionists response for using low discount rates seems rather weak as presented here. Are there any other arguments that would make their position more credible?	IPIECA	18	A	
4	16	9	The estimate of a 15.1% real return to non-residential capital over the period 1975-90 seems very high. The estimates should be properly attributed to their respective authors.	USA	32	G	
4	16	33	Would'nt general economic growth address a large share of the damages from	USA	32	G	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
			warming? Moreover, compensation of future parties that lose from particular policy choices is difficult regardless of the discount rate chosen.				
4	16	33-35	Replace the last two sentences with the following: "Society may not be willing to make other investments, for example in education and research, which could reasonably be expected to benefit those adversely affected by climate change, even hundreds of years in the future. Even if society were willing to make such investments, there is no guarantee that their rate of return would remain where it is today over this entire time period."	USA	32	G	
5	0	0	The conclusion that it is not appropriate to discount for risk or uncertainties is correct.	SWED	17	G	
5	17	1	The existence of multiple market failures is a classic problem of the second best. It is not obvious whether piecemeal fixes would make things better or worse.	USA	32	G	
5	17	19	Footnote 3 is unclear. Risk aversion (declining marginal utility) is supported by data, for example. Agree that it is not clear what the authors are saying about data. Also, what about the data that shows risk loving over losses? Is GCC a problem of losses or gains? Footnote 2 is also unclear. Does "G" refer to the public good? If so, it is not defined until 7 pages after the endnote shows up.	USA	32	G	
6	18	17	If there is no intertemporal welfare maximization by the government, then how can one assert that market rates are necessarily wrong? Couldn't the lack of intervention be viewed as an endorsement of market rates?	USA	32	G	
6	18	21-30	It is unclear from the text just what a shadow price is.	USA	32	G	
6	18	29	The work presented by Lyon at the IPCC meetings show that a shadow price of capital of 1.5 to 2 may be quite low, given the rates of time preference assumed by Cline and others. For example, with no reinvestment of capital income(except for coverage of depreciation), a rate of time preference of 2%, and a return to capital of 8%, the SPC will be 4.0. If 10% of net returns to capital are reinvested, the SPC rises to 6; and if 20% of net returns are reinvested, the SPC rises to 16. Moreover, if the rate of time preference is 1.5% - as is argued several times in this chapter - then the SPC under the last set of assumptions would be infinite. (Note that the total weight on costs will be below these values, as only the portion of costs coming from investment gets weighted by the SPC).	USA	32	G	

Reference			Comments	Reviewer		ID	Response
Section	Page	Line		(Country #)			
6	19	1	The relationship of the discussion in this Para. to the shadow price of capital approach is unclear.	USA	32	G	
8	21	5- 6	The statement that most evidence from economic history suggests the possibilities for economic substitution is high could be misleading. First of all, there are a number of cases from econmic history which point in the opposite direction. eg. the rapid protection of the ozone layer, the conflicts over water scarcity etc. secondly, it does create the impression that "no single resource is indispensable" but it is obvious that there might exist several essential functions of nature which life can not be without and which we can not compensate for. Thus the burden of proof lies on those those who claim that substitutability is possible in all cases since they put the rest of humanity in jeopardy.	SWED	17	G	
9.1	23	24	This derivation of the discount rate needs further elaboration. Equation 4A.1 should be maximized, and the relationship of the interest rate to this equation should be explained.	USA	32	G	
9.1	24	4	Again, intergenerational equity can be far more complex than determination of Q.	USA	32	G	
9.1	25	20	Again, the discount rate would not be negative if prices are appropriately adjusted. See this reviewers comments on p. 6, line 38 of this chapter.	USA	32	G	
9.1	25	23	The relationship of the Sandmo-Dreze approach to the SPC approach is unclear.	USA	32	G	
9.1	26	7-11	The point being made here is not very clear.	CAN	24	G	
9.2	27	17	Should the statement refer to G=U or G not equal to U?	USA	32	G	



EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

MEMBER

April 18, 1995

MEMORANDUM FOR EILEEN CLAUSSEN

FROM: JOSEPH STIGLITZ *JS*
SUBJECT: NEXT STEPS IN CLIMATE NEGOTIATIONS

Congratulations on making significant progress at the first Conference of the Parties in the face of great challenges. As you can imagine, I find the initiation of an international pilot program on joint implementation to be especially heartening.

In thinking about the next set of COP activities, the analytic and assessment phase of the negotiations stands out as an important area of work in the near-term. It is of particular interest because of CEA's experience with the Intergovernmental Panel on Climate Change (IPCC), which has discussed, and in some cases evaluated, some of the same questions being discussed now in the wake of the COP-1. I have attached a preliminary version of the SCOPE chapter (i.e. overview chapter) for the IPCC working group on economics that reflects some of my own thinking.

I look forward to working together in the months to come.

cc: Sally Kane
David Sandilow

MEMORANDUM

COUNCIL OF ECONOMIC ADVISERS

MARCH 13, 1995

MEMORANDUM FOR: JOE STIGLITZ
SALLY KANE

FROM: MIKE TOMAN 

SUBJECT: IPCC WGIII MATERIALS

I know this is the 11th hour plus, but I would like to offer a few comments mainly on the discounting chapter (chapter 4). I have looked at several of the other chapters and did not have too much to say about them, though (a) I did not read chapter 2, (b) I still disagree with the exhaustible resource characterizations in chapter 1, and (c) I am uneasy about the possible false sense of precision in the summaries of damages (since this is a Kane area of expertise I am sure it has already been addressed). I would suggest a clarification of the insurance arguments/analogies in chapter 1. The policy recommendations are to reduce risks, not reallocate them, and there are no actuarial tables to consult since the risks themselves are unknown. These are presumably additional reasons (along with, e.g., contract enforcement) why a private market in climate change damage insurance is unlikely to materialize too soon.

I also must say that the January 20 version of the policy statement is pretty hard to read. It does not convey a clear message or economic story; rather, it is a jumble of assertions. It justifies precautionary measures based on "estimated" damages (p2); it does a poor job (pp2-3) of characterizing the insurance argument; and it does not address the leakage problem clearly (p4). I hope you have had some success in improving this product.

On chapter 4: frankly, Joe, I'm confused -- not by the content of the arguments but by their characterization. The chapter seems to be asserting that it is looking at the issue from the utilitarian perspective, rather than a less axiomatic Rawlsian or other approach. But as far as I can tell, once equation (4.1) is derived the argument goes off into a wide ranging discourse about why the impatience term should be zero or very small. The assumption that $\rho=0$ seems to be maintained in the ranges of numerical estimates offered.

While I am actually sympathetic with the argument, it does not seem right to characterize it as utilitarian since ethical arguments are being invoked to override individual preferences. One might argue that what is being represented is the suppression of impatience in some broader social welfare function, but this function is not specified and it is not the discounted utility of consumption integral specified throughout the paper as the social welfare function. In short, it seems as ad hoc an approach as others that are criticized in the paper.

The problem, it seems to me, is that an effort is being made to derive general statements about intergenerational social welfare tradeoffs from a set-up (the Ramsey equation) that is too simple to support such an effort. This criticism is similar to Schelling's, and I don't think the box on p4 is an adequate response. We really need to start with a broader conception of the intergenerational social welfare function (ISWF), but doing so introduces all manner of difficulties. Various axiomatic approaches (see work by Page and Ferejohn, building on Koopmans) seem primarily to suggest the plethora of possible ISWFs. Sen's welfarist critique arises more deeply (and needs more than a passing mention) in this approach.

One imperfect but useful way out of this has been introduced in the OLG literature, in which the intergenerational discount rate differs from the intragenerational rate. This explicit differentiation of impatience and ethical judgments provides a crucial degree of freedom to deal with the issues in this chapter in a more consistent fashion. It is unfortunate that there is no mention in this chapter of the large and growing OLG literature, not to mention some of the recent social choice work alluded to above.

Some nitpicks:

p2) it is not necessarily correct to characterize agreement to "general egalitarianism" as "widespread," though again I would count myself among the adherents

p3) the inheritance of a world with more of every resource is a red herring; the critical issue is substitutability (p21)

pp9, 19, maybe elsewhere) the capacity of technical change to offset diminished function of natural systems is an empirical issue

p10) in comparing seemingly similar ROR on capital in poor and rich countries, aren't the former incredibly noisy?

p11) the empiricism leading to marginal utility elasticities of 1-2 needs a great deal more explanation so that readers can see where the numbers come from

p21) is it possible that people put higher weight on intergenerational equity than intragenerational equity simply because they do -- that time is not a measure of empathic distance, but (say) the future is a powerful symbol of hope while people in the present are expected to cut it on their own? Alternatively, is it possible that people have the same or greater potential sympathy for others today, but that sympathy is masked by institutional failures that fail to coordinate aid, assure against moral hazard, etc.? Maybe this also explains a seeming reluctance to act more decisively on intergenerational concerns as well -- or maybe people are just selfish! Speculation on what are two potentially different values is inherently risky. These are not very informed questions, but I hope they indicate a line of questioning that other economists might undertake.

I hope these comments are useful; please let me know if you have any questions or comments on them. Thanks.



MEMBER

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

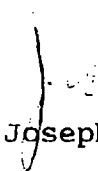
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January 9, 1995

Dear Ram:

Thank you for your invitation to participate in the writing of the Synthesis Report, which I am pleased to accept. Given the importance of the Synthesis report, I did want to express one major concern: the creditability of the entire IPCC process and its usefulness for future Framework negotiations will depend critically on its reflecting accurately the general consensus of the economic science community. I was accordingly surprised to see that there was only one other "establishment" economist among the list of fifteen prospective members. I think it would be highly desirable to have one other economist, preferably with a strong empirical bent, such as Richard Richels, Jae Edmunds, or John Wyant.

Sincerely,


Joseph E. Stiglitz

Dr. Narasimhan Sundararaman
Secretary of the IPCC
IPCC Secretariat
World Meteorological Organization Building
41 Avenue Guisepe-Motta, C.P.N. 2300
1211 Geneva 2
SWITZERLAND



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE



CC: *RS*
SK

To: Prospective members (See attached list)

cc: Prof. B. Bolin
Chairman of the IPCC

From: N. Sundararaman
Secretary of the IPCC

Date: 20 December 1994

Subject: IPCC Drafting Team on the IPCC Study of Article 2
of the UN FCCC - nominations

Total: 5
Pages

Dear Colleague,

1. As you know, the IPCC will write a Synthesis Report (the IPCC Synthesis Report or ISR) based on a review of its Working Groups' Summaries (see IPCC Procedures for Preparation, Review, Acceptance, Approval and Publication of IPCC Reports). The IPCC has also been engaged in examining scientific-technical issues related to achieving the objective (Article 2) of the Climate Change Convention. A workshop on the subject has been held in Fortaleza (17-21 October 1994). The Synthesis Report will include the results of the IPCC examination of Article 2. An underlying report may also be prepared by the IPCC.

2. The ISR has to be drafted, reviewed, revised and approved line by line by the IPCC. It will undergo review sequentially by selected experts and by governments before submission to IPCC for approval. The approval will take place at the eleventh session scheduled for Italy (exact venue to be specified) on 11-15 December 1995. A Drafting Team will be formed under the chairmanship of Prof. Bolin to draft the ISR and to prepare any underlying report. The underlying report will not undergo approval.

3. The IPCC Chairman, the Co-Chairs of the Working Groups viz., Sir John Houghton, Drs. Meira Filho, Watson, Zinyowera, Bruce and Hoesung Lee, the Leaders of the 3 Technical Support Units viz., Drs. Callander, Moss and Haites and the IPCC Secretary will form the core of the Drafting Team. The core team is responsible for the completion and the approval of the ISR.

Post-It™ brand fax transmittal memo 7671		# of pages > <i>5</i>
To: <i>RAY Squitieri</i>	From: <i>LISA Borch</i>	
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IPCC Secret
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MITZERLAND
199 OMM CH

4. The philosophy of selecting the other members of the Drafting Team has been to achieve, as far as practicable, a balance both geographically and in points of view and to invite persons of international eminence who are very active in relevant subject areas including policymaking.

5. The core team invites you to be a member of the Drafting Team. If you agree, you will have to attend a meeting in Athens from 1 to 4 May 1995 (the IPCC Trust Fund will support the travel of the members from the 'developing and transitional economy countries'). The schedule is tentative with regard to 4 May. A proposed schedule for the completion of the Synthesis Report is attached.

6. Can I have your response as to your willingness to serve on the Drafting Team as soon as possible but no later than 9 January 1995?

Many thanks and regards. Happy Holidays.

Yours sincerely,



N. Sundararaman

Proposed Time Table for the completion of the
IPCC synthesis report

All dates are in 1995

Activity	Deadline
First draft to be ready	April 10
First Meeting of the Drafting Team, Athens Result: Second draft for review by selected experts Selection of experts for this review	May 1-3 (possible stay over for some on May 4)
Second draft mailed for review by selected experts Time for return of reviews: 4 weeks	May 8
Experts' Reviews due	June 6
Reviews collated and sent to Drafting Team	June 26
Second Meeting of the Drafting Team, London Result: Third draft for governments' review	July 3-5
Dispatch of third draft for government review Time for return of reviews: 8 weeks (required: 5 weeks)	July 10
Reviews received from governments	September 4
Reviews collated and sent to Drafting Team	September 20
Third Meeting of the Drafting Team, Washington D.C. Result: Final draft for approval at IPCC-XI	September 27-29
Dispatch of the final draft to governments: 6 weeks (required: a month)	October 30
Approval of final draft, IPCC-XI, Italy	December 11-15

Prospective members:

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To	RICHARD RICHES, ~~EPRI~~ From Ray SUTHERI	
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J. Stiglitz	USA	Lead Author, Chapter I, WG III
M. Parry	UK	Convening Lead Author, IPCC Guidelines for Assessing Climate Change Impacts and Adaptations
J. Melillo	USA	Lead Author, WG I/WG II
J. Goldemberg	Brazil	Convening Lead Author, Chapter I, WG III
Martha Perdomo	Venezuela	Co-Chair, Subgroup D/WG II
Tariq Banuri	Pakistan	Lead Author, WG III on equity & social considerations
Zhou Dadi	China	Lead Author, Chapter on emission scenarios, WG III
R. Odingo	Kenya	Co-Vice-Chair, WG III
Roberto Acosta Moreno	Cuba	Lead Author, Energy Supply Mitigation Options, WG II
Penny Wensley	Australia	Ambassador for environment and to UN in Geneva, Vice-Chairman of INC/FCCC
I. Mintzer	USA	Lead Author, WG III
M. Jefferson	UK	Lead Author on energy supply mitigation options (WG II), World Energy Council
B. Gardner	USA	Represents US industry, such groups as Climate Council

J.-C. Hourcade	France	Economist, lead author on the costs of mitigation (WG III)
TBD	TBD	Impacts expertise preferably water, nomination awaited from Bob Watson

Please note that the WMO, and hence the IPCC Secretariat,
will remain closed from 24 December 1994 to 2 January 1995,
reopening on 3 January 1995.

SCHOOL OF BUSINESS ADMINISTRATION

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to: JES

FAX COVER SHEET

DATE: December 15, 1994

TO: Dr. Ray Squitieri

Telefax (202) 395-6958

FROM: Prof. Akihiro Amano

School of Business Administration

Kobe University

Rokko, Kobe 657, JAPAN

Phone 078-881-1212 ext. 3451

Telefax 078-881-8100

NUMBER OF PAGES: 1 (including cover page)

Thank you very much for your facsimile of December 14. It is a neat and nice summary. I have no further comment except that the first line of para. 7 seems to be read "Issues of efficiency and equity can be . . ."

Best regards.

Sincerely yours,





202-395-5036 phone
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Sally K.
Notebook

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①

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Joe-

Here are a few important dates for upcoming IPCC related activities (I told Erik Flaides that you would participate, schedule permitting, in first two of these activities):

September 8, 9, 10 Lead authors meeting in Geneva

- entire 1st draft of report will be discussed

October 10, 11, 12 meeting of Nobel prize winners in economics in France

- to discuss WGI report
- presentations from each writing team will be made

October 17th (week) meeting in Fortaleza, Brazil

- to discuss Article 2 of Framework Convention (estimate damage from anthropogenic greenhouse gas emissions, thresholds for when damage becomes significant ...)
- requested by negotiating committee on climate convention
- requires more synthesis across disciplines than has occurred thus far
- will comprise major chapters of IPCC overall synthesis document



(2)

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I am finishing editing last sections for SCPE chapter. Jose Goldemberg was unhappy with tone, ~~and~~ international context, and lack of discussion of Bob Williams' work. He has received from CEA several edited sections (economics has remained true to versions you have read). My deadline for completed material to him is July 15.

Social Science Subcommittee :

- Methods group will meet July 15 to discuss package of recommendations for budget years 1996/1997.
- Bob Watson did meet with US Geologic Survey director to promote social science, especially value of scientific information. We ~~will~~ ^{will} work closely with him to develop this area more fully with NOAA & NASA.
- You and I should discuss merits of meeting with TJ Glavthier to see interest in promoting social science in next budget season.
- I have spoken with Coe Marrett, Charlie Kennel (NASA - mission to Planet Earth - 1 Billion observing system), Dan Newton about meeting w/you to discuss social science data concerns. We should consider having Ev Erlich participate so we can better integrate (at least coordinate) major data efforts.



2

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National Science and Technology Council

MRC's suggestion of cross-cutting social science group to be placed in fundamental science committee was agreed to by H. Varmus and N. Lane but they want cross cutting groups for other disciplines as well. We will continue to work with MRC to push this idea more forcefully;

Bst 2000 plan

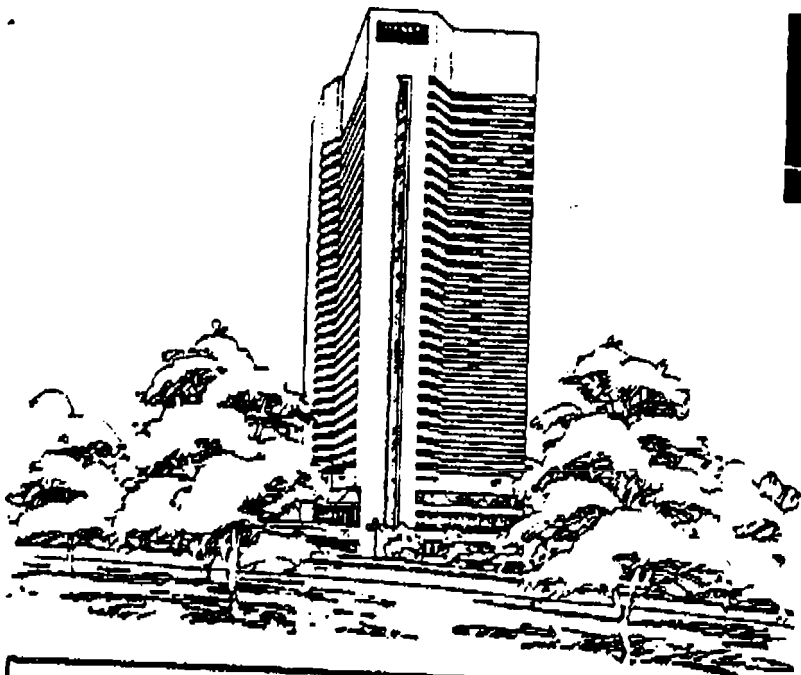
As currently envisioned, plan has serious flaws. The steering group is not very supportive of Bob Watson's plan for setting the context using 3 paper writing exercises. Furthermore, the mission agencies are being asked for possibly a lot of new work, when we do not have any specific mandate from the White House. Lastly, an interim report is planned for December 1994, before much ^{relevant} information being developed for CCAP will be ready. I believe the credibility of this effort will suffer.

Farm Bill

Erik and I have begun to plan out areas for CEA emphasis. We are working to put together a request to ERS and ARS (of USDA) for information.

• I am back in the office July 17th.

Sally



We
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EVERYTHING.

In the heart of beautiful
downtown Vancouver,
close to fabulous shopping
and exciting attractions.

TO : Joseph Hightz
FAX NO. : 202-395-6947 (395-5036 phone)
DATE : July 5, 1994
FROM : Sally Kane

Hyatt Regency Vancouver
655 Burrard Street, Vancouver, British Columbia, Canada V6C 2R7
Telephone: (604) 683-1234 Fax: (604) 689-3707

There are 4 page/s in transmission including this cover page. If all pages are
not received, please call to be resent.

Sender's comments:

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Notebook / IPCC

List of Workshops

WORKING GROUP III WORKSHOPS (Attendance by invitation only)

January 17-20, 1994
Japan

Policy Instruments and their Implications

A workshop on policy instruments and their implications, Tsubuka, Japan.

April 7-8 , 1994
Brazil

Greenhouse Gas Emissions Scenarios

A workshop on the review of current emissions scenarios, Fortaleza, Brazil.

April 27-29, 1994
Italy

Top-Down and Bottom-Up Modelling: What Can We Learn from Each Approach?

A workshop on top-down and bottom-up modelling and what we can learn from each approach, Milan, Italy.

July 18-22, 1994
Kenya

Equity and Social Considerations: What is Science? What are Values?

A workshop on equity and social issues related to climate change, Nairobi, Kenya.

August 1994??

Sustainable Development, Cost-Benefit Analysis and Decision Making Related to Global Warming

Saudi Arabia has indicated that it might be interested in hosting a workshop for WG III.

WORKING GROUP III EXTENDED WRITING TEAM MEETINGS (Attendance by invitation only)

March 3-6, 1994
Switzerland

Decision-making Under Uncertainty & CC Risk Economics

A meeting dedicated to discussing decision making under uncertainty as it applies to climate change, Montreux, Switzerland.

Summer 1994??

Social Costs of Climate Change Tentative

A meeting dedicated to estimating the social costs of climate change.

IPCC WORKSHOPS OF INTEREST TO WORKING GROUP III

The IPCC has been specifically requested to provide advice to the first Conference of the Parties (COP) to the Framework Convention on Climate Change (FCCC) on Article 2 of the Convention. This advice is expected to be based on the results of two workshops.

April 11-14, 1994
Brazil

First Workshop on Article 2 of the FCCC

The first workshop will deal with emissions scenarios, stabilization of atmospheric concentrations, regional climate change scenarios, and implications for impact assessments. This workshop which will be held in Fortaleza, Brazil, April 11 - 14.

August, 1994
Zimbabwe

Workshop on Desertification

WG II is organizing a workshop on desertification to be held in Harare, Zimbabwe in August, 1994. It is expected that adaptation, mitigation, and socio-economic impacts will be important issues for this workshop.

January, 1995

Second Workshop on Article 2 of the FCCC

The second workshop will be held in January, 1995.

NON-IPCC WORKSHOPS OF POTENTIAL INTEREST TO WG III

April 5-8, 1994
Arizona, USA

Global Climate Change. Science, Policy and Mitigation Strategies

A meeting dedicated to global climate change: science, policy and mitigation strategies, Phoenix, Arizona, sponsored by The Air and Waste Management Association.

June 1 - 3, 1994
Groningen, Netherlands

International Conference on Joint Implementation

Organized by the Foundation International Development Economics in cooperation with the Netherlands' Ministry of Housing, Physical Planning, and the Environment.

June 6 - 8, 1994
Denmark

Conference on Abatement Costing

Organized by RISO.

EQUITY AND SURVIVAL

Who provides global benefit; who causes global disbenefit? A basis for the reform of global institutional arrangements.

A Global Commons Institute Paper by Aubrey Meyer and Anandi Sharan

The following ideas emerged over the last two years as part of GCI's research project on "*Equity and Survival*". The ideas were developed through interaction with many delegates [especially from developing countries] to the International Negotiating Committee for a Framework Convention on Climate Change (INC_FCCC). This paper is written partly as a recommendation to the Inter-governmental Panel on Climate Change Working Group Three (IPCC_WG3) on "*Economic and other Cross-Cutting Issues*". The Panel will produce its Second Assessment Report by 1995.

1. Impact, Income and Population; Per Capita Impact, Per Capita Income and Efficiency; 1950 - 1990.

Regional

- **CO2 Impact**¹
- **Income** [measured in PPP\$²]
- **Population**³

are the three basic factors observed.
and the ratios between each, viz

- **CO2 Impact per capita,**
- **PPP Income per capita**
- **Efficiency**⁴ [as Unit of Income per unit of Impact], are assessed.

¹ CO2 data from CDIAC US Energy Dept

² Income data are "*Purchasing power Parity*" (PPP) taken from the Penn World Tables 5.5. These delink national currencies from their exchange rates with US dollar, and value them for domestic purchasing power.

³ Population data from UN Statistics Dept

⁴ Efficiency is the ratio between PPPs and the amount of industrial CO2 (measured in metric tonnes of carbon) emitted to generate the PPPs. CO2 from fossil fuel burning is the principal source of greenhouse gas impact.

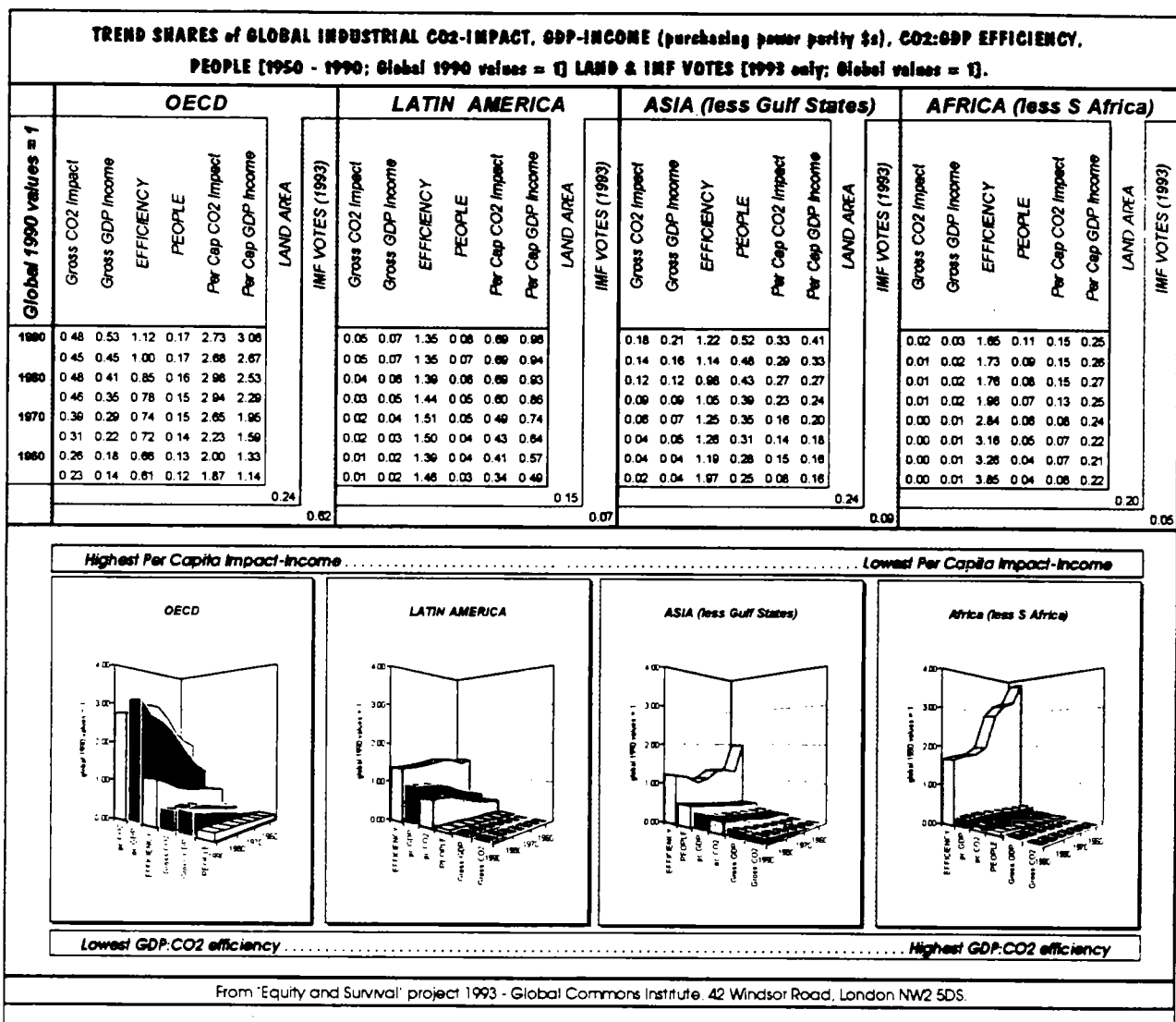
The relative strengths of these are then compared between different parties as proportions of global totals. These comparisons are the beginning of an assessment of the extent of "*global benefit*" or "*global disbenefit*" caused by any party. Global formal sector income is 90% linked to the burning of fossil fuels and the resultant CO2 emissions.

2. Charts and Tables - efficiency trends 1950 - 1990.

Overleaf, four regions of the World are projected: - **OECD, Latin America, Asia** (less Gulf States), **Africa** (less South Africa) with the six indicators mentioned. The indicators are expressed regionally across the period 1950 - 1990 as proportions of global totals for the same indicators. 1990 global values for each are equal to the value of "1.00".

There is a clear trend. High income - both per capita and gross - is accompanied by high impact and low efficiency values. Conversely low income - both per capita and gross - is accompanied by low impact and high efficiency values. The evidence is that there is an inverse relationship between impact/income on the one hand and efficiency on the other. For example, of the regions selected OECD was responsible for nearly 50% of gross global CO2 impact in 1990. From this it derived nearly 60% of gross global income. This impact/income was caused by around 17% of global population.

Thus per capita impact and per capita income in the OECD were at around



three times the global 1990 values for these two indicators. OECD efficiency levels on the other hand, while they rose across the period in question, rose from a low starting point (0.61 of the 1950/55 average global efficiency level) to a higher level (1.12 of the 1985/90 average global efficiency level) at the end of the period.

Conversely Africa was responsible for nearly 2% of gross global CO₂ impact in 1990. From this it derived nearly 3% of gross global income. This impact-income was caused by around 11% of global population. Thus per capita impact and per capita income in Africa were at around one sixth and one quarter

respectively of the global 1990 values for these two indicators. African efficiency levels on the other hand, while they declined across the period in question, fell from a very high starting point (3.85 of the 1950/55 average global efficiency level) to a lower level (1.65 of the 1985/90 average global efficiency level) at the end of the period.

3. Global Benefit & Global Disbenefit

The term "Global Benefit" is used in a number of ways in the current literature on the economics of global climate change. Its use emanates

predominantly from the industrial countries. Partly because it has been developed by bankers interested in lending or granting money, the term has been used in the context of assessing "monetary costs" and so-called "incremental costs" of greenhouse gas abatement measures.

(1) The GEF's Programme for Measuring the Incremental Costs of Protecting the Global Environment (PRINCE) for eg says, *"Since only the global benefits represent the objective of financing, the global community would want to release the new domestic benefits. One way is to sell them (at a price equal to the value, appropriately discounted for time and risk) back to the host country."* This attempts to make global benefit net of domestic benefit. This is contentious and there is no parallel attempt to make domestic benefit net of global disbenefit. The GEF use of the term global benefit is inaccurate and highly provocative.

(2) The term "global benefit" also occurs in Article 3 (Principles), paragraph three of the Climate Change Convention. Article 3 paragraph 3, states that *"the parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost effective so as to ensure global benefits at the lowest possible cost."*

The term "global benefit" is thus central, and captures all the themes of politics and economics arising out of global climate change. On the basis of distribution of *impact, income* and *efficiency* (as shown in the tables and charts on page two), we can say that;

- there are parties which *provide global benefit whilst suffering sub-global disbenefit* and that
- there are parties which *derive sub-global benefit whilst causing global disbenefit*.

Since;

- everyone's interests are subsumed within the unfolding trend of the past, present and future *global efficiency* trajectory,
- this level is itself going to be the result of the net effect of the levels of *global benefit* and *global disbenefit* provision
- this *net global benefit / disbenefit* provision is inseparable from the net levels of global CO2/GDP impact
- current *net global impact* is not yet significantly separable from the inefficiency of global formal sector fossil fuel income generation;

we can say that; -

- global formal sector income is not in reality a private resource, it is a *global common property resource*
- to be used in a globally accountable way to provide and *sustain global common benefit*, and not to provide and sustain *sub-global private benefit* at common expense
- to be used for diminishing and curtailing the provision of *global common disbenefit*, and not be used for sustaining the projection of *sub-global or globally common disbenefit*, especially on third parties by economic institutional means; eg failure to offset carbon-debt against external debt.

4. The inequitable and unsustainable global economic order

We know that today over 90% of formal income globally is derived from the burning of fossil fuels. Calculations by GCI show that

(1) 93% of this income goes to less than one third of the world's population, generated above a sustainable equitable income/impact level and that

(2) the remaining 7% of this income goes to two thirds of the world's population, generated below a sustainable equitable income/impact level.⁵

This has been occurring over time and has been and remains an increasing divergence between the growth of money-less people on the one hand and the growth of people-less money on the other. The former provide global benefit by consuming resources efficiently at sustainable global levels, and the latter is an expression of the inefficient and unsustainable exploitation of resources and represents the provision of global disbenefit. This growing inequity is an expression of growing net disbenefit or declining global survival prospects.

5. Institutional reform and equity.

In the regional tables, each region's share of their voting power at the International Monetary Fund (IMF) is shown at 1993 levels. The IMF is an example of an institution which operates on the basis of allocating rights by income. OECD for example, with over fifty per cent of gross global income has over 60 per cent of IMF voting power.

However, as the data also shows, this is synonymous with allocating rights by impact.

Moreover, those who are least efficient are determining global economic policy. Present institutional arrangements, are thus incompatible with sustainable, equitable outcomes.

Conversely, a global common property arrangement - such as the Climate Convention - allocates voting rights equally on the basis of one party one vote. This is an acknowledgement of the fact that the climate system belongs to everyone equally and indivisibly. The Climate Convention states that; the threat of climate change is "*a common concern of humankind*" and that parties to the Convention should, "*protect the global climate system for the benefit of present and future generations of humankind on the basis of equity.*" Thus there is a direct contradiction between the principles of the Convention and voting practice at the IMF. The IMF voting procedures are merely symptomatic of the broad panoply of inequitable and unsustainable global economic practices which are still in the ascendant at this time.

Reform is inevitable.

Feedback

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With any suggestions on how to these arguments can be used and improved.

⁵ A global per capita equitable and sustainable fossil fuel income/impact threshold for 1990 is calculated as follows: global $(\$/\text{CO}_2)/2.5^{(1)}$

⁽¹⁾ - equivalent to a 60% fossil fuel cut, as per IPCC 1st Assessment Report)



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE



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Handwritten signature/initials

MEMORANDUM

TO: Dr. Joseph Stiglitz

FROM: Dr. Erik Haites

Handwritten signature of Erik Haites

RE: Attached listing

DATE: September 12, 1994

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Kane*

Dear Colleague:

Re: Review of the Draft Chapter on Evaluation of Emissions Scenarios

You are invited to review the enclosed draft chapter on Evaluation of Emissions Scenarios.

The chapter was prepared for Working Group III of the Intergovernmental Panel on Climate Change (IPCC). The final version of the chapter will appear in the IPCC's 1994 Special Report.

The function of the IPCC is to produce "reports on the assessment of available scientific information on climate change...written in such a way as to address the needs of policy-makers and non-specialists".

All IPCC reports are subject to both peer and government review before they are published. Although the peer and government reviews are normally conducted sequentially, they are being conducted simultaneously in this case in order to allow sufficient time for review yet meet the approval and publication deadlines.

If you wish to offer comments on the draft chapter please read the attached information carefully.

The DEADLINE FOR RECEIPT OF COMMENTS is JULY 8, 1994.

Sincerely yours,

James P. Bruce
James P. Bruce
Co-Chair

Hoesung Lee
Dr. Hoesung Lee
Co-Chair

Information for Reviewers
of the draft chapter on
Evaluation of Emission Scenarios

Role of IPCC Assessments

The function of the IPCC is to produce "reports on the assessment of available scientific information on climate change...written in such a way as to address the needs of policy-makers and non-specialists".

IPCC reports consist of three components:

- a Summary for Policymakers which focuses on those key issues which, on the basis of current scientific understanding, IPCC believes should be addressed in the political arena;
- an Executive Summary which contains the highlights of the technical assessment presented in the chapter; and
- a Chapter which critically examines and summarizes available scientific and technical information relating to research and understanding of the subject. While it should avoid complexity wherever feasible, and should not attempt to be a scientific 'text book', this document must allow assertions and conclusions appearing in the Summary for Policymakers to be traced back to the international scientific literature.

The IPCC Review Process

The peer and government review processes are very important steps in the adoption of every IPCC report. You, the reviewer, are being asked to play an important and active part in the evolution of the final version of this document. Please review the draft report and identify parts of the draft text that you believe are particularly good or that do not accurately represent the scientific and technical literature.

Review comments which express agreement with draft text, particularly where the issue is complex or sensitive, are positively encouraged. This helps to avoid the danger of important text, which may be widely but silently accepted by most reviewers, being adversely altered in response to a few critical comments. Reviewers

are also asked to suggest, wherever possible, *solutions* to errors they find rather than simply flagging them.

All comments submitted by reviewers are logged by the WG III Technical Support Unit before being passed (without identifying the reviewer) to the lead authors for assimilation in to the draft report. Final disposition of review comments is the responsibility of the lead authors in consultation with the Working Group III Bureau. In recognition of the important part played by reviewers their names will be listed in an appendix to the final, published report.

Nature of this Draft

This draft is circulated for scientific and government review. *Reviewers are asked to concern themselves only with the specific aspects of the draft, and not with typographic, spelling or purely editorial matters.* Editorial work to unify style and correct typographical and other text-related errors will come at a later stage in the process.

Timetable

In general, it greatly helps the whole process if review comments are submitted as soon as possible.

The last date for receipt of review comments is **Friday, July 1**. This leaves only three weeks in which to integrate the review comments and distribute the revised draft to countries in advance of the Working Group III Plenary meeting to adopt the report.

Submission of Review Comments

Enclosed with this letter is a proforma 'Cover sheet for review comments'. Please use this as a master copy for photocopying. It will greatly ease the handling of your review comments both by the Technical Support Unit and by the lead authors if you use separate cover sheets for comments relating to different parts of the chapter.

All review comments should be sent to:

Erik Haites
IPCC WG III Technical Support Unit
145 King Street West
Suite 1002
Toronto, Ontario M5H 3X6
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After logging each submission, the TSU will pass comments directly to the lead authors. To avoid confusion please do not send a copy of your comments direct to the lead authors.

IPCC WGIII 1994 Evaluation of Emissions Scenarios

Cover sheet for review comments

Date of draft: May 1994

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EVALUATION OF EMISSIONS SCENARIOS POLICY MAKERS SUMMARY

DRAFT

This chapter assesses the adequacy of the IPCC's existing emission scenarios; the economic, demographic and technological projections on which they are based; and the appropriate uses of emission scenarios in scientific assessment and policy making.

Emissions scenarios are projections of future emissions based on specific assumptions about key determinants such as population, economic growth, energy intensity, land use and emissions control policies. Emissions scenarios differ from emissions profiles, emissions targets, and emissions trends in that they postulate explicit causal relationships between key determinants and emissions. The IPCC's existing emissions scenarios are *not* forecasts. Their purpose is not to predict actual, or most likely level, of future emissions, but to explore possible future emissions given the evolution of the key determinants.

The value of emissions scenarios, especially for projections as far ahead as 100 years, has been questioned, since the key determinants for such scenarios are increasingly uncertain with time. The key determinants are population growth; growth in Gross Domestic Product; or *other* economic indicators; energy intensity (the energy used per unit of GDP); carbon intensity of energy consumed and changes in land use.

However, emissions levels for the next century are needed for analytical purposes, such as input to climate models and assessment of the costs of climate change policies. For some of these purposes trends or other simple emissions projections are adequate. But other analyses require data on population, economic growth, energy use or other key determinants of greenhouse gas emissions so scenarios must be used to ensure consistency.

Evaluation of scenarios requires a definition of purpose. Four possible purposes of emissions scenarios are defined:

1. As input to global climate models to project climate consequences of "no intervention" to reduce global greenhouse gas emissions.
2. Climate consequences of intervention to reduce global greenhouse gas emissions.
3. Feasibility and costs of mitigating greenhouse gas emissions for different regions and/or sectors.
4. Input to negotiations for emissions reductions by countries.

1 Mandatory and recommended criteria for emissions scenarios intended for each of these
2 purposes are proposed in the body of the Report.

3
4 The six emissions scenarios published by the IPCC in 1992 (IS92 scenarios) were
5 developed for purpose 1. They project energy-related CO₂, land use-related CO₂, and
6 emissions of other greenhouse gases. Very few other scenarios are as comprehensive. The
7 IS92 scenarios also provide detail for four regions.

8
9 The IS92 scenarios are compared to other scenarios by major category of emissions
10 globally and for selected regions. Energy-related CO₂ emissions are the most frequently
11 studied, but only a few non-IPCC scenarios of land use related CO₂ emissions were
12 available for comparison. The comparison reveals that among the key determinants of
13 greenhouse gas emissions in all scenarios are population, economic growth and
14 technological development.

15
16 Comparison of the IS92 and other emissions scenarios indicates:

- 17
18 ■ A very wide range of **projected emissions**, (a factor of 50 from low to high
19 in 2100), and of input assumptions. The six IS92 scenarios encompass all but
20 a few "outliers";
- 21
22 ■ The range of projected emissions attributable to different models is relatively
23 small (only a factor of 2 to 4 in 2100), the huge balance is due to the **range**
24 **of assumptions** about the key inputs;
- 25
26 ■ **Cumulative emissions** to 2100 have a range of a factor of 7 between the
27 lowest and highest scenarios;
- 28
29 ■ From Working Group I we know that the range of 7 for cumulative emissions
30 leads to **atmospheric concentrations** that differ by a factor of 2; and
- 31
32 ■ There is a **strong central tendency** to all scenarios out to 2050, but it
33 disappears after that.

34
35 The IS92 scenarios cover a wide range of GNP scenarios, but several other scenarios
36 assume lower GNP growth rates. The IS92 scenarios have both the highest and the lowest
37 estimates of population in 2100. As to other input assumptions, the range of E/GNP is
38 narrower and the range of C/GNP is lower for the IS92 scenarios than for other published
39 scenarios. Although the range of values for some inputs to the IS92 scenarios is not
40 representative of the range found in the literature, the resulting emission estimates of the
41 IS92 scenarios do in fact span the range of estimates of other published scenarios.

42
43 Land use emissions of CO₂ are to % of total emissions in the IS92 scenarios. The
44 IS92 scenarios for CO₂ from deforestation are on the lower end of the estimates found in

1 the literature. Emissions from deforestation decline in most scenarios after 2040 due to
2 assumptions about disappearing forest or reduced expansion of agricultural land.

3
4 The IS92 scenarios provide more comprehensive treatment of emissions of greenhouse
5 gases other than CO₂ than is commonly found in the literature. Although only a few other
6 scenarios are available for comparison, the IS92 scenarios span the range of emissions
7 found in the literature.

8
9 At the regional level, time permitted examination of only four regions for energy-related
10 CO₂ emissions. The IS92 emissions for Central and Eastern Europe and the former USSR
11 are higher than those in more recent studies and the IS92 emissions for the U.S.A. span a
12 somewhat lower range than is found in the literature.

13
14 The wide variation in CO₂ emission scenarios, especially in the latter half of the next
15 century, appears to depend most heavily on the range of assumptions relating to economic
16 activity and population growth, followed by the assumptions concerning changes in carbon
17 intensity and energy intensity.

18
19 The IS92 scenarios are suitable for studies of the climate consequences assuming "no
20 intervention" to limit greenhouse gas emissions. They meet all of the mandatory and most
21 of the recommended criteria for purpose 1. These emissions scenarios span the range of
22 estimates of global emissions found in the literature and in this way reflect the current
23 range of views and uncertainty for future emissions. They are more comprehensive than
24 many of the other scenarios available in the literature. However, the input data and
25 methodology are not accessibly documented to allow other researchers to reproduce the
26 scenarios, some of the input assumptions fall outside the range found in the literature, and
27 little information is available about sensitivity analysis of the scenarios. The IS92 emissions
28 scenarios are not suitable for purposes 2, 3 or 4.

29
30 Emissions scenarios should be updated periodically to reflect demographic, economic,
31 technological, scientific and institutional developments. Scenarios for "no intervention",
32 such as the IS92 scenarios, will be affected by such recent developments as:

- 33
34 ■ the change in economic systems in Eastern Europe, Russia and parts of
35 Central Asia,
36
37 ■ economic structural adjustment programs in some developing regions,
38 especially Latin America and Africa,
39
40 ■ the signing of several free trade agreements, especially GATT and NAFTA,
41
42 ■ programs to control acid rain emissions and their implications for greenhouse
43 gases and aerosols.
44

1 The signing and ratification of the Framework Convention on Climate Change and its
2 Annex 1 would not affect "no intervention" scenarios such as the IS92 emissions scenarios.
3 However such climate change policy developments must be reflected in scenarios developed
4 for purposes 2, 3 or 4.
5

6 Procedures for updating or developing emissions scenarios for all four purposes, that will
7 facilitate their assessment, are recommended in this report.
8

9 The IPCC sponsored development of the IS92 emissions scenarios because of the dearth of
10 comprehensive emissions scenarios available in the literature at the time. Several research
11 groups are now able to develop comprehensive emissions scenarios but they have not yet
12 organized themselves for this purpose. It is appropriate to ask whether the IPCC should
13 continue to update the emissions scenarios or limit its role to assessing the scenarios
14 literature.

15 The capacity to prepare emissions scenarios for developing countries and countries with
16 economies in transition must be enhanced. These countries will soon account for over half
17 of the anthropogenic greenhouse gas emissions, yet the baseline emissions inventories, data
18 relating to key determinants of emissions, and modelling capabilities are often severely
19 limited.
20

21
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An Evaluation of the IPCC IS92 Emission Scenarios

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Chapter 6 An Evaluation of the IPCC IS92 Emission Scenarios

IPCC Second Assessment WG III

CONTENTS

Executive Summary

6.1 Background and Scope

- 6.1.1 Terms of Reference
- 6.1.2 Criteria for Evaluation

6.2 The IPCC IS92 Scenarios

6.3 Comparison of Scenarios Related to Energy

- 6.3.1 Global Energy Scenarios
 - 6.3.1.1 Results from Global CO₂ Emission Scenarios
 - 6.3.1.2 Components of Global CO₂ Emission Scenarios
 - 6.3.1.3 Global Emission Scenarios for Other Greenhouse Gases
- 6.3.2 Regional Energy Scenarios
 - 6.3.2.1 China and Centrally Planned Asia
 - 6.3.2.2 Eastern Europe and former Soviet Union
 - 6.3.2.3 Africa
 - 6.3.2.4 USA
- 6.3.3 Sensitivity of Emission Scenarios
- 6.3.4 Discussion

6.4 Comparison of Scenarios Related to Land Use

- 6.4.1 Results from CO₂ Global Scenarios
- 6.4.2 Results from CO₂ Regional Scenarios
- 6.4.3 Factors Affecting CO₂ Emissions from Deforestation
 - 6.4.3.1 Deforestation Rates
 - 6.4.3.2 Carbon Content of Vegetation
- 6.4.4 Results from Global Scenarios of non-CO₂ Greenhouse Gases
- 6.4.5 Results from Regional Scenarios of non-CO₂ Greenhouse Gases

6.4.6 Factors Affecting non-CO₂ Emissions from Land Use

- 6.4.6.1 Factors Affecting CH₄ from Rice Production
- 6.4.6.2 Factors Affecting CH₄ from Enteric Fermentation
- 6.4.6.3 Factors Affecting N₂O from Fertilized Agricultural Soils

6.4.7 Discussion

6.5 Evaluation of IS92 Scenarios

- 6.5.1 Energy Related Scenarios - How Different Are Their Results?
 - 6.5.1.1 Global Results
 - 6.5.1.2 Regional Results
- 6.5.2 Energy Related Scenarios - How Do Their Inputs Compare?
- 6.5.3 Land Use Related Scenarios - How Different Are Their Results?
 - 6.5.3.1 Global Results
 - 6.5.3.2 Regional Results
- 6.5.4 Land Use Related Scenarios - How Do Their Inputs Compare?
- 6.5.5 Population and GNP Assumptions of the IS92 Scenarios
 - 6.5.5.1 GNP Assumptions
 - 6.5.5.2 Population Assumptions
 - 6.5.5.3 The Relationship Between GNP and Population
- 6.5.6 What Are the Uses and Limitations of the IS92 Scenarios?

6.6 Recommendations

- 6.6.1 The Question of New Scenarios
- 6.6.2 The Process of Developing New Scenarios
- 6.6.3 Integrated Scenarios
- 6.6.4 Dissemination of Scenarios

EXECUTIVE SUMMARY

Scenarios of greenhouse gas emissions play an important role in the analysis of potential climate change. From a scientific standpoint, they provide a departure point for analysing the potential occurrence and impacts of climate change; from the policy perspective they can provide information about the consequences of action or inaction to reduce greenhouse gas emissions. Recognizing this pivotal function, the IPCC undertook the development of a comprehensive and international set of emission scenarios as part of their First Assessment (1990). Shortly thereafter (1992) their original reference scenario, SA90, was updated with new information and six new reference scenarios were developed -- IS92 *a* through *f* (reported in the Supplement Report to the IPCC First Assessment in 1992).

This report presents an evaluation of the IS92 scenarios (the SA90 and other scenarios from the IPCC First Assessment Report are not evaluated). Other published scenarios are also taken into account, but only by way of comparison with the IS92 scenarios. It is emphasized that this evaluation only deals with non-intervention scenarios, that is, scenarios that do not assume any policies to directly reduce greenhouse gas emissions. It only briefly considers policy scenarios for the purpose of comparing them to the IS92 scenarios. It can be argued that the "reference" scenarios should take into account emission reductions specified in the now-ratified Climate Convention. However, non-intervention reference scenarios will still be needed as a benchmark for estimating the costs and benefits of policy action versus inaction.

Because of the very limited time available for this evaluation, it focuses exclusively on CO₂, CH₄ and N₂O emission scenarios from energy and land use activities. Other sources of greenhouse gas emissions, other gases, or carbon sinks are not included. Time constraints also made it impossible to evaluate scenario results for all regions. Therefore, the evaluation was limited to a few case study regions from the industrialized and developing world. It is also important to note that no other scenarios were evaluated other than the IS92 scenarios. Therefore the reader should be aware that any shortcomings of the IS92 scenarios identified in this evaluation may also apply to other

published scenarios.

Criteria for Evaluation

Since there are no generally accepted procedures for evaluating these or other kinds of scenarios, a new framework for evaluation is proposed which consists of a set of purposes of scenarios, together with the requirements to satisfy these purposes. It is emphasized that this framework, should be considered very preliminary. The following purposes of scenarios are proposed:

- Purpose 1. To evaluate the environmental/climatic consequences of "non intervention", i.e. no action to reduce greenhouse gas emissions.*
- Purpose 2. To evaluate the environmental/climatic consequences of intervention to reduce greenhouse gas emissions.*
- Purpose 3. To examine the feasibility and costs of mitigating greenhouse gases from different regions and economic sectors, and over time. This can include setting emission reduction targets, and developing scenarios to reach these targets. It can also include examining driving forces of emissions in order to identify which driving forces can be influenced by policies.*
- Purpose 4. As input for negotiating possible emission reductions for different countries and geographic regions.*

It should be noted that the mixed scientific/policy nature of scenarios makes it difficult to separate out scientific from policy objectives. Indeed, both Purposes 1 and 2 have scientific and policy goals. For example, Purpose 1 satisfies the scientific goal of using emission scenarios to explore future states of the global climate system, and the policy goal of assessing the consequences on climate and society of not intervening to reduce emissions.

For each of the above purposes, certain mandatory and recommended requirements are proposed in the

body of the report.

To help judge whether the IS92 scenarios fulfill the requirements of Purposes 1 through 4, they have been compared to other published scenarios.

Energy Related Scenarios - How Different Are Their Results?

Global Results

There are many more scenarios related to energy than to land use because of the larger contribution of energy activities to the emissions of CO₂. The models and methods used to estimate energy related emissions are also more detailed and advanced than those used to compute land use related emissions. Consequently much of the comparison of scenarios focuses on this type of scenario. The following can be said of their results:

- The set of global CO₂ scenarios examined have hugely varying pathways that diverge with time, although nearly all show an upward trend.
- The range of estimates is not so substantial over the medium-term (up to year 2025), ranging from 6.7 to 19.8 Pg C a⁻¹ (or alternatively Gt C a⁻¹). However, over the long-term (up to 2100) the range of estimates widens to a factor of 50, from 1.2 to 60.0 Pg C a⁻¹.
- Although there is a huge range in emission estimates, this range can be explained mostly by the input assumptions of the scenarios, particularly economic growth or activity, population growth, and energy and carbon intensity. Another significant factor is the uncertainty of the models or other methods used to compute the scenarios.
- The time pathways of the six IS92 scenarios fall within the majority of published scenarios, ranging in the year 2100 from 4.6 to 35.8 Pg C a⁻¹.
- Published uncertainty studies of future CO₂ global emissions also report an enormous range of future estimates, from 2 to 87 Pg C a⁻¹ for year 2100 (for the 5th and 95th percentiles of the uncertainty distributions). The IS92 scenarios also fall within the range of these estimates.
- The cumulative emissions of the published scenarios over the period 1990 to 2100 have a considerably smaller range, spanning from 492 to 3447 Pg C (a factor of 7). Cumulative emissions are especially important from the climate impact perspective because of the lag time of build-up of CO₂ in the atmosphere. This implies that the range of estimates of future emissions are less uncertain for climate impact analysis than for other uses of scenarios.

As compared to CO₂, there are far fewer published scenarios of non-CO₂ emissions. For these scenarios an additional source of uncertainty is important, namely, the uncertainty of *current* emission estimates. This means that non-CO₂ scenarios have an overall lower reliability than CO₂ scenarios. IS92 estimates of energy related CH₄ and N₂O emissions have a range of a factor of 6 to 7 in the year 2100. These estimates overlap with the few other published scenarios.

Regional Results

As for *regional* CO₂ emission scenarios, there are far fewer regional estimates than global estimates, with the exception of the USA. The following can be said of the few published scenarios of this type:

- The range of results is about the same as that of global scenarios.
- For the region Eastern Europe and Former Soviet Union, the IS92 scenarios have a higher trend than recently published scenarios that take into account the change in economic activity in these regions.
- The range of IS92 scenarios is on the low side of the range of published reference estimates for the USA.

Energy Related Scenarios - How Do Their Inputs Compare ?

Both the IS92 scenarios and published scenarios rely on large numbers of input assumptions. It was outside the scope of this evaluation to assess the differences between all of these assumptions. Therefore the evaluation focuses on differences between key inputs common to most scenarios, namely, population growth, economic growth (although economic growth is a calculated variable in some scenarios), energy intensity (the amount of primary energy used per unit GNP), and carbon intensity (the amount of carbon emitted per unit GNP). Energy intensity is input to some scenarios, and in others it is derived from scenarios results. Carbon intensity is always derived from scenario results.

- Nearly all scenarios show a downward trend of energy intensity. The energy intensity of the IS92 scenarios overlaps with other scenarios but is partly outside their range.
- Carbon intensities in the published scenarios both decreased and increased, whereas in the IS92 scenarios carbon intensity always declines.
- Assumed changes in energy and carbon intensity have an important influence on estimates of emissions, especially in the second half of next

century.

- The range of economic growth assumptions of the IS92 scenarios is representative of the range of other global scenarios (this applies to scenarios of both energy and land use emissions). Economic growth rates of the IS92 scenarios are generally lower than historical rates. Nevertheless, the assumed rates in the IS92 scenarios would lead to large increases in per capita GNP in all regions.

- The medium IPCC population assumption (IS92a) is equal to the most recent World Bank medium estimate and is close to the most recent medium estimates of the UN and IIASA.

- Of the scenarios reviewed, the IS92 scenarios have the lowest and highest global growth rates of population. The low estimate (IS92c) results in declining global population in the 21st century. These estimates are taken from UN projections, and are not inconsistent with other recent high and low estimates.

- It is outside the scope of this report to evaluate the various critical issues related to population projections such as population aging, earth's carrying capacity, and the relationship between economic development and demographic trends. More research is needed to improve our understanding of these issues so that we can better judge the consistency and likelihood of population projections, and in turn improve our estimates of future emissions.

- In general, the input assumptions of the IS92 scenarios are fairly representative of published global scenarios, but not of published regional scenarios. For example, the IS92 scenarios span a much smaller range of assumptions of future energy intensity for China and the USA than the set of published scenarios. Hence the IS92 scenarios only represent part of the range of regional perspectives contained in the published scenarios.

Land Use Related Scenarios - How Different Are Their Results?

Global Results

Scenarios related to global land use emissions are much fewer in number than those of the energy system. As with energy-related emissions, global estimates are more common in the literature than regional estimates. The following can be said about global CO₂ scenarios related to land use:

- The time paths of published non-intervention scenarios vary considerably, with a maximum difference of 0.8 to 4.8 Pg C a⁻¹, a factor of six. However, in contrast to energy-related emissions which diverge with time, these scenarios deviate

most at mid-century and then converge to zero (by 2100, their range is from 0.0 to 0.8 Pg C a⁻¹). This is because by around 2050 the driving forces of deforestation stabilize or because forests are depleted.

- The IS92 scenarios fall within the lower range of other published global CO₂ scenarios.

- As with energy-related emissions, the range of cumulative emissions over the period 1990 to 2100 (80 to 320 Pg C for non-intervention scenarios) is considerably smaller than range of annual emission estimates for year 2100. Above it was noted that this is significant from the point of view of climate impact analysis. Cumulative emissions have an upper limit given by the maximum available amount of terrestrial biomass that could be oxidized, i.e. around 600 Pg C. In contrast, there is no similar upper limit to energy-related emissions foreseen in the next century.

Regional Results

With regards to the few published regional land use scenarios of CO₂ and other greenhouse gases, there are very considerable differences between the scenarios; the IS92 scenarios sometimes fall within the range of other scenarios and sometimes outside. The range of emission estimates is about the same for regional scenarios as it is for global scenarios, and the scenarios converge in a similar way by the year 2100.

Land Use Related Scenarios - How Do Their Inputs Compare?

- The assumed rate of deforestation is the most important factor influencing emissions of CO₂ related to land use. Most scenarios make very simple assumptions about the driving forces of deforestation, although some scenarios are based on models that simulate land conversion. The different ways of representing deforestation lead to different estimates of deforestation rates, although the published scenarios agree that forest clearing will diminish by 2100 for the reasons cited above.

- Assumptions about carbon content of vegetation also strongly influence estimates of CO₂ emissions.

- In general, estimates of current land use emissions are more uncertain than estimates of current energy-related emissions. As a result, the scenarios have different estimates of base year emissions, and this leads to greater differences between scenarios in their future estimates of emissions.

- Scenario results also differ from one another because the scenarios use very different methods to describe the land use processes which generate

emissions. This reflects the lack of knowledge or agreement on how to represent these processes.

- The IS92 scenarios do not take into account the feedback of climate to land use emissions, and this is one reason why their results differ from other scenarios. However, climate feedbacks are quite uncertain, and including them in estimates of land use emission scenarios may or may not improve these estimates.

- In general, the IS92 scenarios do not cover the range of input assumptions found in published scenarios related to land use.

What Are the Uses and Limitations of the IS92 Scenarios?

In evaluating the IS92 scenarios it is important to recall that they were developed only to accomplish Purpose 1. The IS92 scenarios clearly fulfill the "mandatory" requirements of this purpose. Specifically, their global results span the range of results of published scenarios, and in this way can be said to reflect the current range of views about future emission estimates. Moreover, the IS92 scenarios are among the most comprehensive scenarios available in their coverage of all important greenhouse gases and precursors of ozone and sulfate aerosol. Also the scenarios are sufficiently documented in reports and in digital form to allow their comparison with other scenarios. As a consequence, they are useful for Purpose 1, namely as input to atmosphere/climate models for examining the environmental/climatic consequences of not acting to reduce greenhouse emissions.

It is noted that the IS92 scenarios do not fulfill all of the "recommended" requirements for Purpose 1 listed in Table 1.

Although the IS92 scenarios were designed with Purpose 1 in mind, it is still interesting to question whether they are useful for the other purposes of scenarios. With regards to Purpose 2 (evaluating the consequences of intervention to reduce emissions), the IS92 scenarios make assumptions about controlling local air pollution problems and these measures would also have an affect on greenhouse gas emissions. Moreover, the IS92b scenario includes information available in 1992 about the goals of OECD countries for stabilizing or reducing CO₂ emissions. This information, however, must be updated with the latest information on emission targets. In general, it was found that emission estimates of the IS92 scenarios are substantially higher than policy scenarios

published in the literature. Hence, they should not be used as intervention scenarios.

The IS92 scenarios are inadequate for Purpose 3 (estimation of feasibility and costs of policies) primarily because they do not include mitigation measures specifically targeted towards global warming (they were also not intended for this purpose). In addition, they have limited use as reference scenarios for mitigation studies because their input assumptions and results do not have sufficient detail for geographic regions and sectors. Another reason is that regional results and input assumptions of the IS92 scenarios do not cover the full range of views found in published scenarios.

The IS92 scenarios are not appropriate for Purpose 4 (input to negotiating possible emission reductions) because of the high uncertainty of current greenhouse gas estimates from many sectors and countries. It is again noted that the scenarios were not intended for this purpose.

The Question of New Scenarios

At this time, it is recommended that researchers use the IS92 scenarios as input to atmosphere/climate models for examining the consequences of not acting to reduce greenhouse gas emissions (Purpose 1).

As to the likelihood of individual IS92 scenarios -- the input assumptions of the IS92a scenario are in some cases intermediate as compared to other published scenarios. In addition, the population estimates of IS92a are equal or close to the medium estimates recently published by three different international organizations. However, sensitivity analysis showed that there are no strong reasons for selecting it as the "medium case" scenario. Therefore, at this time, analysts are encouraged to use the full range of IS92 scenarios for Purpose 1, rather than any individual IS92 scenario.

In general, because the IS92 scenarios were not designed and are not suitable for Purposes 2, 3, and 4, new scenarios may be needed to fulfill these purposes. It is worth repeating that the evaluation did not judge the suitability of non-IS92 scenarios to satisfy these purposes. New scenarios, if developed, should include improvements in the estimation of non-CO₂ emissions, particularly from the land use sector.

Although we did not judge the adequacy of all currently available scenarios, it is still likely that new reference scenarios will be needed to fill some gaps in information: For example:

- New *non-intervention* scenarios are needed to take into account recent events that will affect the trend of emissions, such as (i) economic restructuring, especially in the CIS, Eastern Europe and Latin America, and (ii) consequences of the General Agreement on Trade and Tariffs. (We note that restructuring in Eastern Europe and the CIS were partly taken into account in the IS92 scenarios, but it would be worthwhile to include more recent information about this restructuring.)

- New *non-intervention* scenarios are needed to explore a variety of economic development pathways, for example, a closing of the income gap between industrialized and developing regions.

- New *intervention* scenarios are needed that take into account the commitments that are part of the newly ratified Climate Convention. As one example, a new reference scenario should be developed that contains the emission targets of the Convention.

The Process of Developing Scenarios

If new or updated scenarios are developed under the IPCC or other organizations, it is recommended that the following approach be taken to develop these scenarios. The IPCC should act as an "umbrella" under which different groups can develop comparable, comprehensive emission scenarios. The process for developing scenarios should draw on current experience in harmonizing scenarios and model calculations, by emphasizing the following:

- *Openness*. Scenario development should be open to the wide participation of the research community, particularly from developing countries;

- *Pluralism*. A diversity of groups, approaches and methodologies should be encouraged, although they should be harmonized as noted below;

- *Comparability*. Reporting conventions of input and output should be standardized.

- *Harmonization*. Input assumptions and methodologies of the scenarios should be harmonized in order provide a common benchmark for scenarios from different groups.

To accomplish Purpose 3 of emission scenarios (estimation of feasibility and costs of mitigation measures) it is not only important to analyze the

costs of emission reductions, but also to assess the costs and benefits of the impacts of emissions on the natural environment and society. Therefore, the next generation of emission scenarios should be coupled with their impact on the environment and society in the form of consistent, comprehensive *integrated* scenarios of global change.

New scenarios should be widely disseminated to countries, international organizations, non-governmental organizations and the scientific community. As part of this effort, a central archive should be established to make available the results of new scenarios to any group. Where feasible, the archive should also make available some aspects of the models and input assumptions used to derive scenarios. In addition, special effort is needed to improve the capabilities of researchers to analyze and develop scenarios, especially in developing regions. The IPCC can have a major role in these activities.

6.1 Background and Scope

6.1.1 Terms of Reference

Scenarios of greenhouse gases play an important role in the analysis of potential climate change. From a scientific standpoint, they provide a reference point for computing the potential occurrence and impacts of climate change; from the policy perspective they provide information about the consequences of intervention or inaction to reduce greenhouse gas emissions. Because of their critical role, the Chairman of the Intergovernmental Negotiating Committee for the Framework Convention on Climate Change requested that IPCC prepare "an evaluation of current scenarios of greenhouse gas emissions ..." before the April, 1995 meeting of the Conference of Parties (COP) (UNGA document A/AC.237/30). The Bureau of Working Group III further recommended that this evaluation "build heavily" on the scenarios published in the IPCC 1992 Supplement, and that the major assumptions of these scenarios should be examined and recommendations made for updated or new scenarios (First Session of Working Group III, Montreal, 3 May, 1993, WGIII/1st/Doc.1, Rev.2). At the first meeting of Lead Authors of Working Group III (Seoul, Korea, 6-8 September) it was noted that a written draft of this evaluation should be ready for peer review by Spring 1994. Because of these severe time constraints, it was decided at this meeting to limit the scope of the evaluation in the following ways:

- Only the most recent IPCC scenarios are evaluated since these are the most recent scenarios developed under the IPCC process. These scenarios are reported in the IPCC 1992 Supplement (Leggett, *et al.*, 1992; Pepper, *et al.*, 1992), and are hereafter referred to as the "IS92 scenarios".
- Include other emission scenarios only by way of comparison with the IS92 scenarios. Because the IS92 scenarios are intended to be "non-intervention" scenarios (that is, they do not make assumptions about climate policies that would reduce greenhouse gases) we only compare them with other published "non-intervention" scenarios. Some intervention (or "policy") scenarios are reviewed, but only for comparing them with the lowest IS92 scenarios.
- Focus on emissions related to energy and land use activity because they are the primary sources of greenhouse gases. Time did not allow for an evaluation of air transport emissions. Later, it was also found that there was insufficient time and resources to examine halocarbon emissions.
- Give principal attention to scenarios of CO₂ emissions because of CO₂'s critical contribution to radiative forcing, and lesser attention to scenarios of CH₄ and N₂O emissions. Time was not available to examine precursors of ozone or sulfate aerosols.
- Omit sinks of gases, such as carbon sequestration in forest plantations. An exception is made when scenarios of CO₂ from deforestation are discussed; part of the discussion of deforestation concerns carbon uptake by vegetation.

An appropriate question at the outset is, "Who is the audience for this evaluation?". The Work Plan of Working Group III implies a broad audience by asking for recommendations on new scenarios that would "... serve the needs of climate modeling, planning of response measures, and provision of information to the Conference of Parties ...". Indeed, scenarios by nature have both scientific and policy aspects, and it is not particularly fruitful to try and separate out these aspects. As a result, this report provides information relevant to both scientific and policy applications of emission scenarios.

In this chapter we first present the criteria for the evaluation, and then a brief overview of IS92 scenario assumptions and results. This is followed by a comparison of the IS92 and other scenarios during which we examine much more closely the assumptions and results of the IS92 scenarios. Finally, an evaluation of the scenarios is presented, together with recommendations.

Box 1. Terminology Related to Emission Scenarios

<i>Emissions Scenario</i>	Projections of future emissions based on specific assumptions about key determinants such as population, economic growth, energy intensity, land use trends, or emission control policies.
<i>Non-Intervention Scenario</i>	An emissions scenario that does not make any assumptions about climate policies to reduce greenhouse gases. In this report, used interchangeably with "reference scenario"
<i>Intervention Scenario</i>	An emissions scenario that makes assumptions about climate policies to reduce greenhouse gases. In this report, used interchangeably with "policy scenario".
<i>Emissions Profile</i>	Levels of future emissions derived directly or indirectly from a specific objective.
<i>Emissions Target</i>	A target emissions level for a particular date.
<i>Emissions Trend</i>	A projection of future emissions that is not based on specific determinants or objectives.

6.1.2 Criteria for Evaluation

A scenario, in the most general sense, is "a sequence of events", or "an account of a projected course of action or events" (Webster's Ninth Collegiate Dictionary, 1989). An emissions scenario is specifically a projection of future emissions based on specific assumptions about key determinants such as population, economic growth, energy intensity, land use trends, or emission control policies. Sometimes scenarios are mixed up with emission profiles, targets, and other concepts (see Box 1). Emission scenarios are also sometimes confused with the methodology used to generate them. In most cases emission scenarios are generated with a mathematical model(s) or other computational tools, although in some cases they are developed in a more ad hoc manner. This chapter focuses almost exclusively on scenario results and input assumptions rather than on the methodology behind them. This is because much more time would be needed to properly assess the methodology of the scenarios.

Because emission scenarios fall in the grey area between science and policy, it is difficult to select an appropriate benchmark to judge them. Moreover, time constraints of this

1 evaluation made it impossible to develop a rigorous framework for the evaluation.
2 Consequently the following paragraphs should be taken as a very preliminary first attempt to
3 develop such a framework.

4 We begin by proposing the general purposes of greenhouse emission scenarios, and
5 then specify the requirements to meet these purposes (Table 6.1).

6
7 *Purpose 1. To evaluate the environmental/climatic consequences of "no intervention" to*
8 *reduce greenhouse gas emissions. For this purpose a non-intervention scenario*
9 *is devised and then input to a climate or similar model to evaluate the*
10 *scenario's environmental/climatic consequences.*

11
12 This is the most straightforward purpose of emission scenarios. In this case, a non-
13 intervention emissions scenario is developed, and is then input to a climate model which
14 computes the effect of the emissions pathway on the build-up of greenhouse gases, changes
15 in temperature, precipitation, and other climate variables. Results from the climate model are
16 then sometimes used to evaluate impacts of climate change on sea level rise, agricultural
17 production, and other indicators. This type of emissions scenario also serves as a reference
18 point for the intervention scenarios developed for Purpose 2 below, and for assessing the
19 benefits of reducing greenhouse gas emissions.

20 The first two requirements for Purpose 1 (Table 6.1) are related to the use of the
21 emissions scenario as input to a climate model. First, the scenario must be *comprehensive* in
22 its coverage of all important greenhouse gases, so that changes in radiative forcing are not
23 underestimated by the climate model. Second, there needs to be adequate documentation of
24 emission estimates so that input files for the climate model can be prepared. For scientific
25 completeness, there also needs to be sufficient documentation of input assumptions and output
26 of the scenarios to allow for comparisons with other scenarios. In connection with the
27 credibility of the scenario, it should give a "reasonable" view of the future in the absence of
28 climate policies. How to judge this "reasonableness"? One approach is to investigate if the
29 emission estimates of the scenario fall within the "range of views" of other published
30 scenarios. This is, of course, a subjective and inexact requirement since "range of views"
31 cannot be precisely defined and, in any event, other scenarios could be equally unreasonable.
32 Nevertheless, it provides a preliminary, practical way to judge a scenario.

33 The preceding paragraphs describe mandatory requirements of scenarios for Purpose
34 1. Recommended requirements that would boost the credibility and usefulness of these
35 scenarios are given in Table 6.1.

36
37 *Purpose 2. To evaluate the environmental/climatic consequences of intervention to reduce*
38 *greenhouse gas emissions. For this purpose an intervention scenario is*
39 *devised, and then input to a climate or similar model to evaluate the*
40 *scenario's environmental/climatic consequences.*

41
42 This is basically the same as Purpose 1 except that the emissions scenario takes into account
43 climate policies for reducing greenhouse gas emissions. For example, the scenario might
44 assume that a carbon tax is imposed in order to reduce CO₂ emissions, or that a program to
45 reduce CH₄ leakage in natural gas pipelines is carried out. Because of its similarity to Purpose
46 1, Purpose 2 has the same mandatory and recommended requirements as Purpose 1. In

1 addition, the policy assumptions of the scenario must be documented well enough to allow
2 policy interpretation of its results. Lastly, to ensure consistency, the policy scenario(s) must
3 include a reference scenario.

4
5 *Purpose 3. To examine the feasibility and costs of mitigating greenhouse gases from*
6 *different regions and economic sectors, and over time. This can include setting*
7 *emission reduction targets, and developing scenarios to reach these targets.*
8 *It can also include examining different driving forces of emissions in order to*
9 *identify the driving forces which can be influenced by policies.*

10
11 This purpose requires more information about the scenarios than the preceding two purposes,
12 because its goal is a realistic assessment (technical and financial) of mitigation measures. This
13 requires estimation of all important greenhouse gases from specific economic sectors and
14 geographic regions. Input assumptions must also be described in this detail. Under ideal
15 circumstances, these data would be available on the country-level, although for preliminary
16 calculations the scale of world regions may be adequate.

17 Analysing the feasibility and costs of mitigation also requires that the scenario have
18 a high level of internal consistency, so that costs can be accurately assessed. In addition, since
19 the evaluation of mitigation measures must take into account the time period over which
20 measures are put into place, a scenario must provide information about changing emissions
21 over time, rather than for a single point in the future (e.g. year 2025). To enhance the
22 usefulness of scenarios for Purpose 3, it is also recommended that a *range* of policy
23 alternatives be explored.

24 Scenarios that fulfill Purpose 3 will also fulfill Purpose 2, namely, to evaluate the
25 environmental/climatic consequences of intervention to reduce gas emissions. But a scenario
26 that fulfills the requirements for Purpose 2 will not necessarily have enough detail to comply
27 with Purpose 3.

28
29 *Purpose 4. As input for negotiating possible emission reductions for different countries*
30 *and geographic regions.*

31
32 There are two aspects to this purpose. The first is that negotiations may require *quantitative*
33 information, for example estimates of future emissions from different regions in order to
34 negotiate quantitative goals for these regions. In this case, the scenario must gain broad
35 international acceptance by being based on widely acknowledged and accepted input
36 assumptions and methodology. Therefore, a scenario must comply with all of the mandatory
37 and recommended requirements of Purpose 1 if it is to be used as a non-intervention reference
38 case, and all the mandatory and recommended requirements of Purpose 3 if it is to be used
39 to illustrate emissions resulting from climate policies.

40 The second aspect is that negotiations may only require *qualitative* information, e.g.,
41 the relative importance of one emission category over another. In this case, only the
42 mandatory requirements of Purposes 1 and 3 must be fulfilled.

43 It is our opinion that Purpose 4 is difficult to achieve at this time because of the high
44 uncertainty of current greenhouse emissions from many emission categories and in many
45 countries (especially CO₂ in non-energy sectors and other greenhouse gases from virtually all
46 sectors). Nevertheless, scenarios for Purpose 4 will soon be needed for discussions related to

the Climate Convention.

The reader should note that Purposes 1 and 2 fulfill both scientific and policy objectives. From the scientific side, emission scenarios are used as input to models for exploring future states of the global climate system, and from the policy perspective they are needed to assess the consequences on climate and society of reducing or not reducing greenhouse gases.

For each of the preceding purposes, proposed "mandatory" and "recommended" requirements are summarized in Table 6.1. These requirements are used throughout this chapter to evaluate the six IS92 scenarios. For clarification, we note to the reader that the requirements in Table 6.1 are applied not only to individual scenarios but to *sets* of scenarios, as in the set of six IS92 scenarios.

Table 6.1: Requirements for Using Emission Scenarios for Different Purposes

Mandatory	Recommended
<u>Purpose 1</u>	
<i>Comprehensive.</i> The scenarios take into account all important greenhouse gases including precursors of ozone and sulfate aerosol.	<i>Reproducible.</i> Input data and methodology are documented adequately enough to allow other researchers to reproduce the scenarios
<i>Documentation of Output.</i> Sufficient detail is provided for emissions by type, region (if available) and sector, in order to allow comparisons with other scenarios.	<i>Input Data (and Model Parameters) Should Reflect Current Range of Views.</i> Data on driving forces, as well as parameters in the case that a model is used, reflect the current range of views. In addition, derived variables, for example, carbon intensity of the economy, also reflect current understanding.
<i>Emission Estimates of the Scenario Reflect a Range of Views.</i> A single reference scenario is inadequate for this purpose. Instead, a range of scenario results are presented that take into account the uncertainties of basic driving forces of the scenarios.	<i>Sensitivity Analysis.</i> Information is provided on the sensitivity of scenarios output to variation and uncertainty of input data and model parameters (if a model is used).
	<i>Internal Consistency.</i> The various input assumptions and data of the scenarios are internally consistent. For example, assumptions about biomass in the energy sector are consistent with assumptions in the land use sector.

Table 6.1: Continued

Mandatory	Recommended
<u>Purpose 2.</u>	
All requirements of Purpose 1 listed above, and in addition:	All requirements of Purpose 1 listed above.
<i>Documentation of Assumptions about Policy Intervention.</i> All assumptions about policy actions are documented adequately enough to allow policy interpretation of the scenario results. <i>Reference Scenario.</i> The set of emission scenarios include a "Reference Scenario" for comparison with the policy scenarios in order to ensure consistency.	
<u>Purpose 3.</u>	
All requirements of Purpose 1 listed above, and in addition:	All requirements of Purpose 1 listed above, and in addition:
<i>Disaggregation of Data.</i> Input and results of scenarios are sufficiently disaggregated into sectors and geographic regions to allow analysis of policies. The geographic breakdown is the country-level, but the regional level may be adequate as a first step.	<i>Range of Policy Actions.</i> The set of scenarios include a wide range of policy alternatives.
<i>Documentation of Input Data and Methodology.</i> Input data and methodology are sufficiently documented to allow analysis of feasibility and costs of reduction measures.	
<i>Internal Consistency.</i> The methodology and various input assumptions and data of the scenarios are internally consistent.	
<i>Temporal Calculations.</i> The scenarios describe the time aspect of implementing mitigation measures. This is critical information for assessing costs of control.	
<u>Purpose 4</u>	
If <i>quantitative</i> information is required for negotiations, then scenarios must comply with all <i>mandatory and recommended</i> requirements of Purposes 1 or 3.	
If only <i>qualitative</i> information are required for negotiations, then scenarios must comply with only <i>mandatory</i> requirements of Purposes 1 or 3.	

Box 2. Earlier IPCC Scenarios

The most recent IPCC scenarios, the IS92 scenarios, are a continuation of the work of the Response Strategies Working Group of the First Assessment of the IPCC (IPCC, 1990). One of this working group's activities was to produce four global emission scenarios extending to year 2100:

(1) "Business as Usual" (also known as "2030 High Emissions") which assumes that few steps are taken to limit emissions. This scenario results in a doubling of equivalent CO₂ in the atmosphere (relative to pre-industrial levels) by around year 2025.

(2) "2060 Low Emissions" in which some steps are taken to reduce the growth of emissions such as implementing the Montreal Protocol and halting tropical deforestation. The effect of this scenario is a doubling of equivalent CO₂ by year 2060.

(3) "Control Policies" which assumes that steps, in addition to those prescribed in "2060 Low Emissions" are taken to reduce emissions, especially that non fossil fuel energy plays a more important role after 2025. As a result, the atmospheric concentration of equivalent CO₂ stabilizes by year 2090.

(4) "Accelerated Policies" in which steps in addition to the "Control Policies" scenario are taken including a much larger role for commercial biomass energy. The result of these emissions is that equivalent CO₂ stabilizes in the atmosphere at less than double its pre-industrial level.

The Energy and Industry Sub-group (EIS) of the Response Strategies Working Group elaborated an additional "EIS Reference Scenario" which provided additional detail for CO₂ and CH₄ emissions from energy and industry (IPCC, 1991) up to year 2025 for different world regions.

6.2 The IPCC IS92 Scenarios

As part of its First Assessment, the IPCC produced four emission scenarios ranging from a high emissions reference case called "Business as Usual" to a lower emissions case called "Accelerated Policies" (Box 2). The need to incorporate new information in the scenarios led to a second scenario building exercise under IPCC, in which the number of reference scenarios was expanded from one to six (Box 2). These scenarios are called the IS92 scenarios, and are the subject of this evaluation. They are described in the Supplementary Report to the First Assessment (Leggett, et al., 1992), and in more detail in Pepper, et al., 1992. The reader is referred to these publications for details about the scenarios; only a brief overview is presented here.

As compared to earlier IPCC scenarios, the IS92 scenarios take into account the following new information: the London Amendments to the Montreal Protocol; revised population forecasts of the World Bank and United Nations; the report of the Energy-Industry Subgroup of IPCC (ESG, 1990); political and economic changes in the former Soviet Union, Eastern Europe, and the Middle East; and new data on tropical deforestation, and sources and sinks of greenhouse gases.

The basic idea of the scenarios is to explore the possible pathways of greenhouse gas

emissions in the absence of climate policies to reduce them. However, the scenarios do take into account control of local air pollution problems, and this leads to reductions in some greenhouse gases. Moreover, the IS92b scenario includes commitments of some OECD countries to stabilize or reduce CO₂ emissions, as they were known up to 1992. Nevertheless, since emission controls in IS92b do not have a large effect on global emissions, we will refer to the entire set of IS92 scenarios as "non-intervention" scenarios. The scenarios are among the most comprehensive ever developed in their coverage of all important greenhouse gases - carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), halocarbons, sulfur oxides (SO_x), and precursors of tropospheric ozone: nitrogen dioxides (NO_x), volatile organic compounds (VOC), and carbon monoxide (CO).

A model of the US Environmental Protection Agency called the "Atmospheric Stabilization Framework" (ASF) was used to develop the scenarios. The model performs calculations for nine world regions. Results for nine regions are available in electronic form, but in IPCC reports these regions have been aggregated into four regions: -- OECD, Eastern Europe and former USSR, China and Centrally Planned Asia, and "Other". The ASF combines various modules for computing emissions from energy, industry, agriculture, forests, and land conversion, which are documented in EPA (1990). Different aspects of these calculations are discussed in the course of this chapter.

In order to explore a variety of possible pathways of future emissions, the IS92 scenarios cover a wide range of assumptions for population, GNP, agriculture, energy and other determining factors. Specific assumptions about population, and other inputs are made for each of the nine individual regions contained in the ASF. An overview of some key assumptions is given in Table 6.2.

Scenario IS92a adopts intermediate assumptions (as compared to the other IS92 scenarios) about population and economic growth. The major difference between the IS92b and IS92a scenarios is, as noted above, that IS92b takes into account information available up to 1992 on the commitments of some OECD countries to stabilize their CO₂ emissions. The IS92a and b scenarios give emission estimates that are intermediate to the other IS92 scenarios (Table 6.3).

The IS92c scenario assumes the lowest rates of population and economic growth and severe constraints on fossil fuel supplies. As a result, this is the lowest emissions scenario, and the only one showing a decreasing emissions trend (Table 6.3). The scenario IS92d assumes the low population growth rate of IS92c but a higher economic growth rate. It also makes additional assumptions about emission controls. The net result is that it has the second lowest future emission estimates.

At the other extreme, the IS92e scenario assumes the highest population and economic growth rates of the IS92 scenarios with plentiful fossil fuels. Consequently, this scenario has the highest estimates of future emissions (Table 6.3). The scenario IS92f uses the high population estimates of IS92e, but lower economic growth assumptions. Hence, it is the second highest emissions scenario (Table 6.3).

Much more is said about the assumptions and results of the IS92 scenarios in the remainder of the report.

Table 6.2: Summary of assumptions in the six IPCC 1992 alternative scenarios.

Scenario	Population	Economic Growth		Energy Supplies	Other	CFCs
IS92a	World Bank 1991 11.3 B by 2100	1990-2025:	2.9%	12,000 EJ Conventional Oil 13,000 EJ Natural Gas Solar costs fall to \$0.075/kWh. 191 EJ of biofuels available at \$70/barrel†	Legally enacted and internationally agreed controls on SO _x , NO _x and NMVOC emissions. Efforts to reduce emissions of SO _x , NO _x and CO in developing countries by middle of next century	Partial compliance with Montreal Protocol. Technological transfer results in gradual phase out of CFC's in non-signatory countries by 2075.
IS92b	World Bank 1991 11.3 B by 2100	1990-2025:	2.9%	Same as "a"	Same as "a" plus commitments by many OECD countries to stabilize or reduce CO ₂ emissions.	Global compliance with scheduled phase out of Montreal Protocol.
IS92c	UN Medium-Low Case 6.4 B by 2100	1990-2025:	2.0%	8,000 EJ Conventional Oil 7,300 EJ Natural Gas Nuclear costs decline by 0.4% annually.	Same as "a"	Same as "a"
IS92d	UN Medium-Low Case 6.4 B by 2100	1990-2025:	2.7%	Oil and gas same as "c" Solar costs fall to \$0.065/kWh 272 EJ of biofuels available at \$50/barrel	Emission controls extended worldwide for CO, NO _x , NMVOC and SO _x . Halt deforestation. Capture and use of emis- sions from coal mining and gas produc- tion and use.	CFC production phase out by 1997 for industrialized countries. Phase out of HCFCs.
IS92e	World Bank 1991 11.3 B by 2100	1990-2025:	3.5%	18,400 EJ conventional oil Gas same as "a" Phase out nuclear by 2075	Emission controls which increase fossil energy costs by 30%.	Same as "a"
IS92f	UN Medium-High Case 17.6 B by 2100	1990-2025:	2.9%	Oil and gas same as "e" Solar costs fall to \$0.083/kWh Nuclear costs increase to \$0.09/kWh	Same as "a"	Same as "a"

† - Approximate conversion factor: 1 barrel = 6 GJ

Source of Table: Leggett, *et al.* (1992)

Table 6.3: Selected results of six IS92 scenarios

Scenario	Scenario year	Emissions per year		
		CO ₂ (PgC)	CH ₄ (Tg)	N ₂ O (TgN)
IS92a	1990	7.4	506	12.9
	2025	12.2	659	15.8
	2100	20.3	917	17.0
IS92b	2025	11.8	659	15.7
	2100	19.1	917	16.9
IS92c	2025	8.8	589	15.0
	2100	4.6	546	13.7
IS92d	2025	9.3	584	15.1
	2100	10.3	567	14.5
IS92e	2025	15.1	692	16.3
	2100	35.8	1072	19.1
IS92f	2025	14.4	697	16.2
	2100	26.6	1168	19.0

6.3 Comparison of Scenarios Related to Energy

In this section we compare the IS92 energy-related emission scenarios to other published scenarios. The goal of this comparison is to determine the degree to which the IS92 scenarios reflect the range of emissions and major input assumptions found in other scenarios at both the global and regional level.

First global and then regional emissions are analysed. Scenarios of CO₂, CH₄ and N₂O are examined, although the IS92 scenarios consider the full spectrum of greenhouse gases. Because of the limited scope of this evaluation, the regional analysis was limited to four regions: China and Centrally Planned Asia, Eastern Europe and the former Soviet Union, Africa, and the United States. These regions were selected because they are in different stages of economic development.

For global and regional emissions we first assess the accuracy of the base year (1990) emission data in comparison to the latest emission inventory based on UN energy statistics (Marland *et al.*, 1989 and 1993). Next, we compare the IS92 emissions to the range of emissions of other published scenarios, and the range spanned by the 18th and 84th percentile (median plus/minus one standard deviation) of the poll of energy scenarios from the International Energy Workshop (Manne and Schrattenholzer, 1991, 1993, 1994). Finally, we compare the main input assumptions and scenario components of the IS92 and other published scenarios.

6.3.1 Global Energy Scenarios

6.3.1.1 Results from Global CO₂ Emission Scenarios

Of all the greenhouse gas emissions carbon dioxide (CO₂) is the most studied. Of all the CO₂ sources, fossil fuel combustion is the most studied. This interest arises from the fact that fossil fuel CO₂ emissions contribute more to potential climate change than any other single gas released by any other single human activity. There is a relatively large literature on global fossil fuel carbon emissions; surveys go back more than a decade to Ausubel and Nordhaus (1983). It is interesting that scenarios developed in the past decade (beginning in 1983) have a narrower range of future emission estimates than those developed in the previous decade. Scenarios no longer anticipate emissions of greater than 90 Pg C a⁻¹ in the year 2050, as considered, for example by Jason (1979), Bacastow and Keeling (1981), and Siegenthaler and Oeschger (1978). The highest estimate of the post 1983 period projects emissions of 35 Pg C a⁻¹ in the year 2050, (Lashof and Tirpak, 1990).

The IS92 scenario estimate of base year (1990) emissions, 6 Pg C a⁻¹, is close to the estimate of 5.9 Pg C a⁻¹ by Boden *et al.* (1992) and Marland *et al.* (1993). Estimates for 1990 from other published scenarios range from 5.4 to 6.8 Pg C a⁻¹.

Future estimates of emissions diverge substantially with time (Figure 6.1), and resemble each other only in that they almost all increase with time. A notable exception is the IS92c scenario. For the year 2025, the spread of non-IS92 scenario emissions is not so substantial, ranging from 6.7 Pg C a⁻¹ in Ausubel *et al.* (1988), to 19.8 Pg C a⁻¹ for Lashof and Tirpak (1990). The IS92 scenarios range between 7.4 (IS92c) to 13.5 Pg C a⁻¹ (IS92e). As another indication of the range of views of the energy community, the 16th and 84th

percentile range from the International Energy Workshop (IEW) scenario poll, is between 6.9 and 10.9 Pg C a⁻¹ for the year 2020.

By the year 2100 the range of non-intervention scenarios expands significantly, with the IS92 scenarios extending from 4.6 to 35 Pg C a⁻¹, a factor of more than seven. The lowest non-IS92 scenario examined is given by Ausubel *et al.* (1988), 1.2 Pg C a⁻¹, while the highest is given by Ogawa (1990) at 60 Pg C a⁻¹, a range of 50. This range also encompasses the range of 12 reference scenarios compared by the Energy Modeling Forum (the "EMF-12" study) (Weyant, 1993). These scenarios span from 20 (Global-Macro) to 43 Pg C a⁻¹ (CETA). The EMF-12 results are particularly interesting because they were obtained from models with harmonized input assumptions about population and economic activity. Consequently, they highlight how future emission estimates can vary because of differences in models rather than differences in input assumptions alone.

Histograms of projected emissions (Figure 6.2) show that emission estimates of scenarios are relatively closely clustered in the year 2025, but they diverge with time. The frequency of the mode also becomes smaller and smaller with time indicating that the scenarios agree less and less about the central estimate of emissions. The interval that contains each of the IS92 cases is also indicated, and shows that the IS92 scenarios bracket a majority of non-IS92 scenarios, but never capture the full range of the non-IS92 reference cases. This is particularly clear for the year 2100. Throughout the period, there are always scenarios with substantially more or less fossil fuel carbon emissions than the IS92 scenario set.

Additional information about the range of future emissions can be obtained by examining results from detailed uncertainty analyses. These were conducted by Nordhaus and Yohe (1983), Edmonds *et al.* (1986), Manne and Richels (1993), and de Vries, *et al.* (1994).

It is noteworthy that despite the enormous range of results produced by the uncertainty analyses (Figure 6.3), emissions almost always increase with time, with the exception of the extremes of results. The uncertainty analysis of Edmonds *et al.* (1986) shows a range of 2 and 87 Pg C a⁻¹ for the 5th and 95th percentile cases respectively in the year 2075, and a range of 4 to 27 Pg C a⁻¹ between the 25th and 75th percentiles. The uncertainty analysis of Nordhaus and Yohe (1983) span the range 12 to 27 Pg C a⁻¹ for the year 2100 between their 25th and 75th percentiles, and 7 to 55 Pg C a⁻¹ between their 5th and 95th percentile cases.

It should be emphasized that these results stem from uncertainties of the model *as well as uncertainties of input assumptions such as population and economic activity* (see Sections 6.3.1.2 and 6.3.3). By comparison, when input assumptions are fixed between scenarios, a much lower range of emission estimates is found. For example, it was noted above that when key model inputs were harmonized in the EMF-12 scenarios, emission estimates in year 2100 varied by only a factor of two rather than over a factor of 40, as found in the uncertainty studies. This is consistent with the recent results of de Vries *et al.* (1994), who only assigned uncertainty to model input parameters, while fixing other input assumptions such as population and economic growth relative to a base case. As a consequence, they computed emission estimates for the year 2050 ranging by only a factor of about two, from 11.3 to 24.4 Pg C a⁻¹ (5th and 95th percentiles).

While published energy-related emission estimates for 2100 vary by a factor 50 between the highest and lowest reference scenarios and by a factor more than 7 in the IS92 scenarios, cumulative emissions have a much smaller variation. The cumulative emissions of the published scenarios over the period 1990 to 2100 (Figure 6.4) vary by a factor 7 (from 492 Pg C in Ausubel *et al.*, 1988, to 3447 Pg in Lashof and Tirpak, 1990). The cumulative

emissions of the IS92 scenarios vary by a factor of 3 between IS92c (700 Pg) and IS92e (2078 Pg). Cumulative emissions of policy scenarios are obviously lower, ranging from 290 Pg (Lazarus *et al.*, 1993) to 600 Pg (Lashof and Tirpack, 1990) in the scenarios reviewed.

Cumulative emissions are especially important in assessing climate impacts because of the lag time in the build up of CO₂ in the atmosphere. Hence, the narrower range of cumulative emissions as compared to the range of annual emissions (implying a lower uncertainty of cumulative emissions) is important from the point of view of climate impact analysis.

The above cumulative emission figures can also be compared to the cumulative energy-related carbon emissions between 1860 to 1990 of about 215 Pg C a⁻¹ (IS92, 1990, Marland *et al.*, 1989, Nakićenović *et al.*, 1993). Thus, even the lowest reference and policy scenarios indicate that more energy-related carbon will be emitted from 1990 to 2100, than from the onset of the Industrial Revolution to the present.

Summing up the discussion of results of global CO₂ scenarios, the scenarios diverge with time and almost all have an upward trend. Their range is much narrower in year 2025 than in year 2100. The IS92 scenarios follow the same pattern, and fall within the range of the majority of published scenarios.

The lowest and highest published scenarios reviewed in this report vary by a factor of 50 in the year 2100. Much of this large range, however, can be attributed to the wide range of assumptions made about driving forces of emissions, such as economic activity and energy intensity. The range of estimates for cumulative emissions between 1990 and 2100 is much narrower than for annual emissions (a factor of 7 versus a factor of 50). This is important for climate impact analysis because of the lag time in the build up of CO₂ in the atmosphere.

6.3.1.2 Components of Global CO₂ Emissions Scenarios

The limited scope of this report makes it impossible to carefully examine and compare all input assumptions of published scenarios. Instead, selected energy-related scenarios are compared by breaking down the calculated emissions into different components:

$$\text{CO}_2 \text{ Emissions} = \text{Population} * (\text{GNP/Population}) * (\text{Energy/GNP}) * (\text{CO}_2/\text{Energy})$$

In this equation, the ratio "Energy/GNP" represents the *energy intensity* (primary energy consumed per unit GNP). Energy intensity data are indexed to 1990 data because of the incomparability of GNP/GDP data in different studies. The ratio "CO₂/Energy" is the *carbon intensity* (carbon emissions per unit primary energy consumed) which reflects the amount of carbon-based fuels used in the energy economy. Carbon intensity is given as kg C per GJ.

Such an approach for analyzing the components of future CO₂ emissions has been proposed by Kaya (1989) and applied by Edmonds and Barns (1992), Ogawa (1991) and Grubler *et al.* (1993) among others. The advantage of this approach is that it makes it possible to compare the input assumptions of all scenarios which provide information on at least emissions, energy use, GNP, and population.

There are some caveats that should be noted. First, for the purposes of this comparison, not only population and income, but all of the components are treated as

independent from one another. This assumption may be inconsistent with some models that assume that components, such as per capita income and energy intensity, are related to one another. Second, the influence of some components on emissions may depend on the aggregation level of the analysis (global versus regional or national). Hence, an analysis of components of emissions on the global level may mask decisive differences between regions. For this reason, the component analysis should only be used to compare the input assumptions of different scenarios and not, for example, for projecting emissions on the basis of population growth in different regions.

Table 6.4 shows the component growth rates of selected scenarios including the IS92 scenarios. The IS92 scenarios are in most instances within the range of alternative scenarios, although not always representative of the range. They span a representative range of global economic growth rates, but the population growth assumptions of IS92c and IS92e are lower and higher, respectively, than any of the published scenarios.

Figures 6.5 and 6.6 depicts the ranges of energy intensity and carbon intensity for published global scenarios. It is noteworthy that all scenarios reviewed showed decreasing energy intensities, with a median value of about 1 percent per year. The IS92 scenarios fall within a majority of published scenarios, although they cover a narrower range, especially up to 2020. There is also a significant overlap particularly before 2020, between the ranges of reference and policy scenarios, although the policy scenarios are generally lower.

Most scenarios assume that carbon intensity decreases at a lower rate than energy intensity (Figure 6.6); in some cases the carbon intensity increases, indicating increased use of carbon-rich fuels such as synthetic fossil fuels or coal (Table 6.4). However, on the average, carbon intensity in the non-intervention scenarios decrease at a rate of about 0.2 percent per year (1990-2020 average). This is somewhat lower than the long-term historical average of 0.3 percent per year (Nakićenović *et al.*, 1993). Up to the year 2020, the rate of carbon intensities assumed in the IS92 scenarios agrees with the IEW and other reference scenarios. However, all the IS92 scenarios have declining carbon intensities. Beyond the year 2020, the range of published reference scenarios shows a much wider variation than the IS92 cases. In some non-IS92 scenarios, carbon intensities increase with time due to a rapid expansion of coal production and use, a case not considered in IS92. Carbon intensities assumed in policy scenarios are generally lower than those of the IS92 and other non-intervention scenarios, although some reference scenarios have quite low carbon intensities as in the case of the "methane economy" of Ausubel *et al.* (1988).

Data from selected scenarios (Table 6.4), indicate that on the average global carbon emissions tend to increase with time first of all because of the assumed increase in per capita GNP, and secondly because of population increases. Emissions tend to decrease primarily because of decreasing energy intensity, and secondarily because of decreasing carbon intensity.

Summing up the discussion of the components of global CO₂ emissions, the economic growth assumptions of the IS92 scenarios fall within a representative range of other published scenarios, while the population assumptions of the IS92 scenarios are higher and lower than other scenarios surveyed. The IS92 assumptions about energy intensity have a narrower range than other published scenarios. The carbon intensity assumptions of the IS92 scenarios all show a downward trend in contrast to the set of published scenarios, some of which increase and some of which decrease with time.

Table 6.4 1990 - 2020 World annual growth rates¹ for selected scenarios

Non-intervention Scenarios ³	POP	GNP Capita	GNP	Energy GNP	Carbon Energy	Carbon Emissions
IS92a	1.40	1.53	2.92	-0.97	-0.24	1.68
IS92b	1.40	1.53	2.92	-1.08	-0.26	1.54
IS92c	1.10	0.92	2.00	-0.86	-0.55	0.56
IS92d	1.10	1.75	2.83	-1.10	-0.68	1.00
IS92e	1.40	2.29	3.71	-1.16	-0.11	2.39
IS92f	1.75	1.36	3.10	-0.85	-0.03	2.19
IPCC-EIS	1.24	1.74	3.00	-0.80	0.05	2.23
IEW-84% ²			3.36	-0.75	0.05	1.95
IEW-50% ²			2.78	-1.16	-0.18	1.44
IEW-16% ²			2.46	-1.71	-0.67	0.63
ECS '92	1.42	0.78	2.21	-0.75	-0.16	1.28
CH ₄ -Efficiency	1.29	0.83	2.13	-0.78	-0.85	0.47
CHALLENGE			2.55	-0.94	-0.18	1.41
WEC A	1.43	2.36	3.82	-1.50	-0.01	2.25
WEC B	1.43	1.85	3.30	-1.84	-0.22	1.17
E&R B	1.13	1.68	2.85	-1.03	-0.23	1.54
EPA-SCW	1.43	0.35	1.79	-0.72	-0.07	0.98
EPA-RCW	1.29	1.35	2.65	-0.70	0.04	1.98
GREEN			2.71	-0.53	0.14	2.31
I2RT			2.50	-0.99	0.00	1.49
IMAGE 2.0-CW	1.40	1.61	3.00	-0.56	-0.25	2.20
Minimum ²	1.10	0.35	1.79	-1.84	-0.85	0.47
Median ²	1.40	1.53	2.83	-0.94	-0.18	1.54
Mean ²	1.35	1.46	2.79	-0.99	-0.21	1.56
Maximum ²	1.75	2.36	3.82	-0.53	0.14	2.39
<i>Policy Scenarios</i>						
Minimum ²	1.17	0.35	1.79	-2.40	-1.94	-1.31
Median ²	1.29	1.35	2.65	-1.78	-1.19	-0.32
Mean ²	1.32	1.37	2.66	-1.74	-1.16	-0.29
Maximum ²	1.43	2.19	3.50	-1.08	-0.52	0.24

1) Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2) Component growth rates do not add as calculated from original frequency distributions.

3) Reference for scenarios given in Appendix 6.1.

BOLD denotes IPCC scenarios

Table 6.5 1990 - 2020 China and centrally planned Asia annual growth rates¹ for selected scenarios

Non-intervention Scenarios ³	POP	GNP Capita	GNP	Energy GNP	Carbon Energy	Carbon Emissions
IS92a	1.03	3.91	4.98	-1.73	-0.32	2.84
IS92b	1.03	3.91	4.98	-1.73	-0.32	2.84
IS92c	0.69	2.98	3.70	-1.61	-0.51	1.51
IS92d	0.69	4.09	4.81	-1.88	-0.57	2.25
IS92e	1.03	4.83	5.91	-2.00	-0.21	3.57
IS92f	1.31	3.75	5.12	-1.57	-0.22	3.24
IPCC-EIS	0.78	4.49	5.30	-2.44	0.30	3.04
IEW-84% ²			5.74	-0.96	-0.29	3.15
IEW-50% ²			4.79	-1.61	-0.38	2.77
IEW-16% ²			3.88	-2.49	-0.38	2.33
ECS '92	0.97	2.01	3.00	-1.02	-0.18	1.76
ESCAPE S1			5.50	-1.42	-0.20	3.78
He <i>et al.</i> (c)	0.68	3.96	4.67	-1.60	-0.34	2.75
WEC A	0.94	5.07	6.06	-2.85	-0.24	2.79
WEC B	0.94	4.08	5.06	-2.40	-0.03	2.51
E&R B	0.91	2.34	3.28	-0.22	-0.52	2.52
EPA-SCW	0.90	2.25	3.17	-0.81	-0.58	1.74
EPA-RCW	1.02	4.11	5.17	-1.21	-0.47	3.41
GREEN			4.40	-0.27	0.25	4.38
12RT			4.03	-1.36	-0.38	2.22
IMAGE 2.0-CW	1.02	4.15	5.21	-0.82	-0.21	4.13
Minimum ²	0.67	2.01	3.00	-2.85	-0.58	1.51
Median ²	0.94	3.91	4.90	-1.59	-0.30	2.85
Mean ²	0.93	3.73	4.66	-1.52	-0.28	2.83
Maximum ²	1.31	5.07	6.06	-0.22	0.30	4.38
<i>Policy Scenarios</i>						
Minimum ²	0.81	2.25	2.34	-4.32	-1.72	-0.82
Median ²	0.94	4.08	4.48	-1.89	-1.06	1.24
Mean ²	0.94	3.70	4.24	-2.24	-1.03	0.86
Maximum ²	1.02	4.11	5.17	-0.53	-0.52	2.29

1) Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2) Component growth rates do not add as calculated from original frequency distributions.

3) Reference for scenarios given in Appendix 6.1.

BOLD denotes IPCC scenarios

Table 6.6 1990 - 2020 Eastern Europe and ex-USSR annual growth rates¹ for selected scenarios

Non-intervention Scenarios ¹	POP	GNP Capita	GNP	Energy GNP	Carbon Energy	Carbon Emissions
IS92a	0.43	1.49	1.93	-0.66	-0.24	1.01
IS92b	0.43	1.49	1.93	-0.66	-0.24	1.01
IS92c	0.31	0.95	1.26	-0.69	-0.50	0.06
IS92d	0.31	1.88	2.21	-1.03	-0.67	0.48
IS92e	0.43	2.83	3.27	-1.37	-0.19	1.67
IS92f	0.67	1.73	2.31	-0.88	-0.13	1.28
IPCC-EIS	0.70	2.49	3.20	-1.14	-0.17	1.84
IEW-84% ²			2.98	-1.06	-0.34	0.46
IEW-50% ²			2.16	-1.42	-0.36	0.07
IEW-16% ²			1.51	-2.01	-0.41	-0.25
ECS '92	0.49	2.18	2.68	-1.52	-0.24	0.88
Bashmakov Base	0.58	0.77	1.36	-0.93	-0.05	0.37
Sinyak <i>et al.</i> BAU	0.56	1.44	2.00	-1.09	-0.41	0.49
WEC A	0.52	1.85	2.38	-1.81	-0.62	-0.10
WEC B	0.52	1.85	2.38	-2.13	-0.38	-0.18
E&R B	0.48	1.62	2.11	-1.07	-0.40	0.61
EPA-SCW	0.52	1.73	2.27	-1.29	-0.17	0.78
EPA-RCW	0.45	3.80	4.27	-2.97	-0.16	1.01
GREEN			2.51	-0.63	0.32	2.19
12RT			2.29	-2.00	-0.29	-0.05
IMAGE 2.0-CW	0.43	1.48	1.91	0.72	-1.62	0.99
Minimum ²	0.31	0.77	1.26	-2.97	-1.62	-0.25
Median ²	0.48	1.73	2.29	-1.12	-0.23	0.61
Mean ²	0.49	1.85	2.63	-1.17	-0.29	0.76
Maximum ²	0.70	3.80	4.25	0.72	0.32	2.42
<i>Policy Scenarios</i>						
Minimum ²	0.37	0.77	1.36	-4.01	-1.96	-1.79
Median ²	0.52	1.85	2.38	-2.41	-1.24	-1.34
Mean ²	0.50	2.26	2.68	-2.59	-1.15	-1.13
Maximum ²	0.58	3.80	4.27	-1.45	-0.21	-0.25

1) Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2) Component growth rates do not add as calculated from original frequency distributions.

3) References for scenarios given in Appendix 6.1.

BOLD denotes IPCC scenarios

Table 6.7 1990 - 2020 Africa annual growth rates¹ for selected scenarios

Non-intervention Scenarios ⁴	POP	GNP Capita	GNP	Energy GNP	Carbon Energy	Carbon Emissions
IS92a	2.63	1.25	3.92	0.26	-0.21	3.98
IS92b	2.63	1.25	3.92	0.26	-0.21	3.98
IS92c	2.20	0.40	2.60	0.40	-0.39	2.61
IS92d	2.20	1.46	3.69	0.09	-0.44	3.32
IS92e	2.63	2.11	4.80	0.17	-0.19	4.78
IS92f	3.03	1.06	4.12	0.51	-0.12	4.53
IPCC-EIS	2.42	1.55	4.00	-0.48	0.46	3.99
IEW - 84% ²			3.82	-0.52	0.10	3.33
IEW - 50% ²			3.64	-0.28	-0.17	3.28
IEW - 16% ²			3.45	-0.63	-0.09	3.06
UNEP base	1.86	2.53	4.44	-1.40	0.47	3.46
WEC A	2.94	2.98	6.00	-0.58	1.17	6.61
WEC B	2.94	2.00	5.00	-1.67	0.26	3.51
E&R B	1.56	2.29	3.89	-1.46	0.07	2.44
EPA-SCW	2.72	0.01	2.73	-0.17	0.86	3.45
EPA-RCW	2.42	1.71	4.17	-0.10	0.72	4.81
IMAGE 2.0-CW	2.63	1.25	3.92	0.53	-0.16	4.30
Minimum ³	1.56	0.01	2.60	-1.67	-0.44	2.44
Median ³	2.63	1.50	3.92	-0.17	-0.09	3.51
Average ³	2.49	1.56	4.00	-0.30	0.13	3.85
Maximum ³	3.03	2.98	6.00	0.53	1.17	6.61
<i>Policy Scenarios</i>						
Minimum ³	1.86	0.01	2.73	-2.19	-4.01	-0.31
Median ³	2.57	1.71	4.15	-1.46	-1.13	1.25
Mean ³	2.51	1.53	4.08	-1.31	-1.47	1.21
Maximum ³	2.94	2.53	5.00	-0.30	-0.11	2.43

1) Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2) Refers to non-OPEC developing countries. Component growth rates do not add as calculated from original frequency distributions.

3) Component growth rates do not add as calculated from original frequency distributions.

4) References for scenarios given in Appendix 6.1.

BOLD denotes IPCC scenarios

Table 6.8 1990 - 2020 USA annual growth rates¹ for selected scenarios

Non-intervention Scenarios	POP	GNP Capita	GNP	Energy GNP	Carbon Energy	Carbon Emissions
IS92a	0.57	2.33	2.91	-1.81	-0.26	0.78
IS92b	0.57	2.33	2.91	-1.81	-0.26	0.78
IS92c	0.22	1.72	1.94	-1.59	-0.63	-0.31
IS92d	0.22	2.45	2.67	-1.94	-0.88	-0.21
IS92e	0.57	2.91	3.49	-1.98	-0.11	1.34
IS92f	0.90	2.09	3.00	-1.62	0.00	1.34
IPCC-EIS	0.56	0.90	1.46	-0.20	0.16	1.42
IEW-84% ²			2.36	-0.88	0.29	1.37
IEW-50% ²			2.20	-0.96	0.24	1.24
IEW-16% ²			2.03	-1.18	-0.22	0.80
ECS '92	0.54	1.09	1.63	-1.21	-0.25	0.15
CHALLENGE			1.28	-0.66	0.03	0.80
EMF 12 (lowest)			2.20	-1.38	-0.24	0.49
EMF 12 (highest)			2.20	-1.04	0.13	1.24
WEC A	0.56	1.83	2.40	-1.94	-0.44	-0.02
WEC B	0.56	1.83	2.40	-2.08	-0.40	-0.13
E&R B	0.51	1.63	2.15	-1.09	0.22	1.26
EPA-SCW	0.53	1.13	1.67	-1.29	0.00	0.35
EPA-RCW	0.43	2.23	2.64	-1.83	0.02	0.81
NES			2.08	-0.32	-0.12	1.63
GREEN			2.27	-0.97	-0.05	1.23
12RT			2.20	-1.06	0.16	1.28
IMAGE 2.0-CW	0.56	2.33	2.91	-2.17	-0.22	0.46
Minimum ²	0.22	0.90	1.28	-2.17	-0.88	-0.31
Median ²	0.56	1.96	2.20	-1.29	-0.11	0.80
Mean ²	0.52	1.91	2.31	-1.35	-0.12	0.79
Maximum ²	0.90	2.91	3.49	-0.20	0.29	1.63
<i>Policy Scenarios</i>						
Minimum ²	0.43	1.04	1.19	-2.88	-2.98	-2.30
Median ²	0.53	1.83	2.14	-1.91	-1.13	-0.97
Mean ²	0.51	1.69	2.08	-1.87	-1.18	-1.08
Maximum ²	0.56	2.23	2.67	-0.66	-0.53	0.73

1) Component growth rates do not add exactly to (sub)totals due to independent rounding errors.

2) Component growth rates do not add as calculated from original frequency distributions.

3) Reference for scenarios given in Appendix 6.1..

BOLD denotes IPCC scenarios

6.3.1.3 Global Emission Scenarios for Other Greenhouse Gases

Although fossil fuel CO₂ is not the only radiatively important gas associated with human activities, far less attention has been paid to non-CO₂ greenhouse gases. Here we compare the IS92 scenarios with the few others available for energy-related CH₄ and N₂O emissions (Alcamo *et al.*, 1994; Edmonds, 1993; Lashof and Tirpack, 1990; Matsuoka *et al.*, 1993; Messner and Strubegger, 1991; and Nakicenovic *et al.*, 1993). The IS92 scenarios provide a broad range of possible future trajectories for both CH₄ and N₂O (Figure 6.7). By the year 2100 the difference between the high and low cases for CH₄ and N₂O is similar to that for CO₂ (that is, a factor of between seven and eight). Of particular importance to CH₄ and N₂O scenarios is the significant uncertainty of base year (1990) emissions, which reflects the gaps in knowledge about the processes which lead to these emissions.

6.3.2 Regional Energy Scenarios

The background report for the IS92 scenarios gives results for four regions: OECD, Eastern Europe and the Former Soviet Union, China and other Centrally Planned Asia, and Rest of the World (Pepper *et al.*, 1992). The original IS92 analysis, however, was conducted for nine regions. For our analysis we use the following regions: China and Centrally Planned Asia, Central and Eastern Europe and the former Soviet Union (EEFSU), Africa, and the United States of America (USA). These were selected because they are in different stages of economic and demographic development. The USA was selected in particular because there are a large number of published scenarios for this region.

Only CO₂ emissions are analyzed because of the scarcity of non-CO₂ regional scenarios in the literature. The main components of the different scenarios for the period 1990-2020 are given in Tables 6.5 to 6.8 and Figures 6.8 to 6.10.

6.3.2.1 China and Centrally Planned Asia

The carbon emissions of the IS92 scenarios are within the range of other reference scenarios. However, their underlying driving forces are not representative of other published scenarios. The IS92 scenarios assume GNP increases that are on the high side of other scenarios, while their range of assumptions about energy intensity and carbon intensity for China is both narrower and lower than the range of other scenarios.

Figure 6.8 shows the range of carbon emission scenarios up to the year 2100. The IS92a, IS92d and IS92f scenarios are well within the range of the IEW poll for 2020. IS92a is consistent with the IEW poll median and consequently can be considered as a "middle of the road" scenario. Conversely both IS92e and IS92c expand the range of all other long-term (2100) emission scenarios reviewed. IS92e is the highest, and IS92c is the lowest of all reference scenarios analyzed.

Analysis of the components in the growth of carbon emissions (Table 6.5) indicates the importance of economic and population growth assumptions followed by decreases in energy intensity. By 2100 IS92e assumes the highest and IS92c the lowest GNP growth rates of all scenarios reviewed. In all scenarios the intensity of energy use decreases typically about 1.5 percent per year in reference cases and well above 2 percent in policy cases (Figure 6.9). The resulting improvements in energy efficiency across all scenarios are large, but within the range of both historical experience and calculations of the theoretical minimum requirements

derived from exergy analysis (cf. Nakićenović *et al.*, 1993). The IS92 scenarios have a narrower range of assumed energy intensities than other scenarios. Most scenarios also anticipate further decarbonization of the energy system, i.e. a decrease in carbon intensity of 0.2 to 0.5 percent per year (Figure 6.10). The IS92 range is lower than other reference scenarios (cf. the IEW poll). Indeed, the low carbon intensities assumed in IS92c, IS92d and IS92e for China in the years after 2050 are more characteristic of policy scenarios than non-intervention scenarios.

6.3.2.2 Eastern Europe and former USSR (EEFSU)

The IS92 scenarios do not fully capture current perceptions about the trends of energy-related emissions in EEFSU in the medium term (up to 2020). First, the IS92 base year (1990) emission estimate (1.7 Pg C a^{-1}) exceeds by 30 percent the most recent estimate based on UN energy statistics ($1.304 \text{ Pg C a}^{-1}$) (Marland *et al.*, 1993). Second, assumptions in the IS92 scenarios about high growth rates (particularly for GNP) are probably unrealistic considering the current economic crisis. This leads to medium term estimates of CO_2 emissions in the IS92 scenarios that are rather higher and narrower in range than other published scenarios (Figure 6.8). The range of IS92 scenarios in 2025 span from 1.8 to 3.0 Pg C a^{-1} , whereas the more recent IEW poll spans a range of 1 to 1.6 Pg C a^{-1} by 2020. Because of the uncertainty of economic trends, the range of medium-term emission estimates from the literature (Figure 6.8) is perhaps the largest for any region.

Most long term scenarios (including IS92) represent more or less a pre-1990 "business as usual" point of view, and do not fully take into account the economic crisis in EEFSU. By year 2100 the published scenarios have a range of over a factor of eight. One reason for such a wide spread is that both IS92c and IS92d are beyond the emission range of other published scenarios, and are more characteristic of policy scenarios.

As expected, the rate of economic growth has the largest range of any input variable (Table 6.6). Recent scenarios (e.g. Bashmakov, 1992 and Sinyak *et al.*, 1992) assume much lower values (nearly a factor of two) than scenarios developed before 1991.

Almost all scenarios agree that both energy and carbon intensities will decline. The projected decline in energy intensity ranges between 1 to 2 percent per year (Figure 6.9), although there are significant differences in assumed short term (up to 2000) and longer term (2020 and beyond) trends. As indicated by results from the IEW poll, short term energy intensities in the region could increase. In fact, between 1990 and 1992 the energy intensity of the former USSR increased by 23 percent (ECE, 1993). Over the longer term, significant improvements in energy intensities could occur following economic restructuring and replacement of inefficient capital stock. The extent and timing of these efficiency improvements is of course uncertain, and is reflected in the scenario ranges of the IEW poll. This range is wider than the range of assumptions used in the IS92 scenarios (Figure 6.9).

Most scenarios also project declining carbon intensities of around 0.3 percent per year (Figure 6.10), although statistical data and base year calibration problems in some models/scenarios remain significant (illustrated by the wide range in 1990 carbon intensities). By 2020, the range spanned by the IS92 scenarios is narrow, but continues to be representative of "middle of the road" scenarios available in the literature. Over the long term (2100) the range of IS92 scenarios is much wider and at the low end of published scenarios. Carbon intensities of the IS92c and d scenarios are close to the values of published policy scenarios (Figure 6.10).

6.3.2.3 Africa

The IS92 scenarios account for half of all the available scenarios of long term energy-related emissions for Africa.

The range of emissions scenarios is among the widest both in absolute and relative terms of all regions covered in this review (Figure 6.8). By 2020 regional emissions range between 0.3 to 0.8 Pg C a⁻¹, and increases to 0.5 to 5.2 Pg C a⁻¹ (i.e. a factor of 10). However even for the highest scenario, per capita carbon emissions by 2100 would still remain significantly below current OECD averages. Overall, the range of absolute emission projections spanned by the IS92 scenarios is in good agreement with the limited number of published scenarios. Conversely, the IS92 scenarios do not well represent the range of driving forces assumed in other scenarios, particularly for energy and carbon intensities (See Tables 6.9 and 6.10).

Up to year 2020, population growth rates dominate over per capita GNP growth (Table 6.7), but afterwards becomes less important than other driving forces (cf. Grubler, 1994). Up to 2020, assumed per capita economic growth rates show a large range (0 to 3 percent per year), with GNP growth rates ranging from 2.6 to 6 percent annually. IS92c assumes the lowest GNP growth rate of all reference scenarios reviewed.

Scenarios differ substantially in their assumptions about energy and carbon intensities up to 2020. Whereas the IS92 scenarios all assume increasing energy intensities (Figure 6.9), all but one of the other scenarios project decreasing energy intensities. Conversely, the IS92 scenarios all project declining carbon intensities (Figure 6.10), whereas all but one of the other scenarios anticipate increasing carbon intensities. The IS92 scenarios also assume a much smaller range of energy intensities than is found in other scenarios (Figure 6.9). The overlap between reference and policy scenarios is another indication of the lack of a common view on trends in Africa (Figures 6.8, 6.9, and 6.10).

6.3.2.4 USA

This region has the largest number of published scenarios available, with over 50 covered in this review. The IS92 scenarios only partly reflect the range of views capture by the published scenarios.

The range spanned by scenarios of future USA emissions is large (Figure 6.8). For 2020, scenario results range between 1.2 (IS92c) to 2.3 Pg C a⁻¹ (e.g. IPCC-EIS, or NES). The IS92 scenarios are skewed to the low side (Figure 6.8). By 2100, the range of published scenarios widens from 0.6 (IS92c) to 4.5 Pg C a⁻¹ (highest scenario from the EMF-12 model runs). The IS92 scenarios range by a factor of five by 2100, and continue to cover the low side of the range of published scenarios.

The upper range of the published scenarios imply a large increase in USA emissions by 2100 (up to 3.2 Pg C a⁻¹). However, this increase is may be unlikely from a developed, service-oriented economy such as the USA, which already has one of the highest per capita emission levels in the world. The lower emission estimates of the other published scenarios support this view.

Assumptions about the trend of energy intensity vary significantly between scenarios, although all scenarios assume a decline in intensity (Table 6.8 and Figure 6.9). The range of energy intensities spanned by the IS92 scenarios (and the IEW poll) appears narrow, especially up to 2020. Over the long term (2050 and beyond) there is also a significant overlap between reference and policy scenarios. One interpretation of this overlap is that

distinction between climate policies targeted towards improving energy efficiency, and efficiency improvements due to other reasons, becomes increasingly blurred in the long term.

Although all non-intervention scenarios assume that energy intensity declines, they do not make the same assumption for carbon intensity. Some show a decrease because of increased reliance on low or no-carbon fuels, while others increase in carbon intensity due to assumptions about greater use of coal, for example. Both IS92c and IS92d assume much lower carbon intensities than other reference scenarios (Table 6.10).

Over longer time horizons, changes in energy intensity and carbon intensity become as important to estimating emissions as changes in population and economic growth (cf. Grubler, 1994). This implies that over the long run, differences in models and parameter assumptions may become more important than uncertainties of future population and economic growth. This conclusion is also supported by results of the EMF-12 exercise (Gaskins and Weyant, 1993, and Weyant 1993). It also suggests that more scenarios are needed to represent a wider range of views on changes in energy and carbon intensity of the future economy.

Summing up the discussion of regional energy scenarios, there are several instances in which emission estimates of the IS92 scenarios are not representative of the range of other published scenarios. In the case of Eastern Europe and the former Soviet Union, IS92 estimates are considerably higher than other recently published scenarios that take into account the current economic situation in this region. For the USA, the IS92 scenarios span a lower range of emission estimates than the range of other published scenarios. The input assumptions of the IS92 scenarios (e.g. economic growth and carbon intensity) are in many cases not representative of other published regional scenarios.

6.3.3 Sensitivity of Emission Scenarios

A sensitivity analysis investigated the relative influence of three factors, GNP, energy intensity, and carbon intensity on energy-related CO₂ emissions. Population is not included as a factor because information about population assumptions are not available for all scenarios reviewed.

The sensitivity of future energy-related CO₂ emissions to variations in critical input assumptions is analyzed in Figure 6.11. Sensitivity is expressed as the change in emissions relative to the IS92a emissions, resulting from changes in GNP/capita, energy intensity, and carbon intensity. Each of these input variables is changed from its minimum to its maximum value given in Table 6.4. All other variables are fixed at their IS92a values.

With regards to non-intervention scenarios over the medium term (up to 2020), assumptions about GNP growth are quite important, followed by energy intensity or carbon intensity (Figure 6.11). Over the longer term (2050 and 2100) energy and carbon intensity become increasingly important in some regions, although GNP growth continues to be the most important factor. If policy scenarios are included in the analysis, then assumptions about carbon intensity become as important as GNP growth assumptions (Figure 6.11).

Comparison of reference and policy scenarios suggests that uncertainties in driving forces of emissions within reference cases are at least as large as the uncertainties between reference and policy cases. This implies that over a long time horizon it is difficult to

distinguish between the effect of climate policies and the effect of societal/technological changes.

If the IS92a scenario were to represent a "middle of the road" view of the different scenarios, then one should expect the uncertainty ranges of emissions to be symmetrically (similar positive and negative values) distributed. Figure 6.11 indicates that this is not the case, especially at the regional level. Thus, the uncertainty analysis provides no evidence to suggest that the IS92a has a higher likelihood than other IS92 scenarios or other energy-related scenarios.

Published uncertainty analyses also provide information about the relative importance of different input assumptions. We have already discussed the emission results of four published uncertainty analyses. Here we discuss their findings regarding the importance of input assumptions. Nordhaus and Yohe (1983) identified ten key input parameters to which they assigned probability distributions. Their analysis singled out the rate of substitution between fossil and non-fossil energy use as the most important parameter in explaining the uncertainty in carbon emissions. In addition, they found the rate of growth of total factor productivity, a measure which affects both labor and energy productivity, to be next most important. Interestingly, population assumptions were low on the list of factors affecting baseline emissions. Edmonds *et al.* (1986) obtained a similar result. However, the range of population growth assumptions used in both uncertainty studies did not encompass the current range of population projections.

Edmonds *et al.* (1986) performed a uncertainty analysis similar to Nordhaus and Yohe (1983), but their model contained much more detail about energy producing and consuming sectors. The carbon emissions forecasts from this study formed a biased distribution with median values significantly below the mean values. Edmonds *et al.* identified the four most important factors in explaining carbon emissions uncertainty as labor productivity in developing countries, labor productivity in developed countries, end-use energy efficiency improvements, and the world income elasticity of energy demand. They did not confirm the finding of Nordhaus and Yohe that the rate of interfuel substitution was an important parameter. This finding can be attributed to the greater detail in the Edmonds, *et al.* model, which included resource constraints and the incorporation of multiple sources of energy supply in addition to interfuel substitution options.

Manne and Richels (1993) performed an uncertainty analysis in which a poll of experts was used to set uncertainty distributions of key input parameters such as GDP growth rates, elasticity of substitution between energy and labor and capital, rate of autonomous energy efficiency improvements (AEEI), commercial year for economically-competitive carbon-free electricity, and the cost of the non-electric backstop technology. They found that the most important parameter was above all the potential GDP growth rates, followed by the AEEI and (to a smaller extent) the two supply side technology parameters. At the same time, the elasticity of substitution between energy and capital and labor only had only a minor influence in reference scenarios (assuming comparatively modest energy price increases), a situation that changes however drastically in policy intervention cases.

As noted earlier, de Vries *et al.* (1994) did not evaluate the uncertainty of model driving forces, but concentrated instead on the influence of uncertain model parameters on scenario results. They found that the most important parameters were the elasticities of energy demand, and the parameters which are used to describe consumer responses to fuel price increases.

1
2 *Summing up the discussion of sensitivity analysis -- Assumptions about GNP growth are quite*
3 *important in estimating future emissions, although in some regions assumptions about energy*
4 *intensity and carbon intensity become equally important over the long term. (Population*
5 *growth was not taken into account in this analysis). From the perspective of this sensitivity*
6 *analysis, there is no evidence to assume that IS92a or any of the IS92 scenarios is a*
7 *"medium" scenario. In addition, results of uncertainty analyses point out that emission*
8 *estimates are sensitive to the structure and processes used in models to represent the real*
9 *world. Consequently, in order to obtain a full range of views about future emissions, it is also*
10 *important to use a wide range of different models and methodologies.*

11 12 13 **6.3.4 Discussion**

14 The global CO₂ estimates of the IS92 scenarios bracket a majority of other published
15 non-intervention scenarios, and therefore, can be considered to reflect a reasonable range of
16 fossil fuel scenarios. While some plausible scenarios fall above or below the range spanned
17 by the IS92 scenarios, the number of such scenarios is comparatively small.

18 In comparison to CO₂ emissions, the literature on non-CO₂ greenhouse related gases
19 is limited. Few other studies considered the variety of gaseous emissions reported by the IS92
20 scenarios. An important reason for the divergence of emission estimates for non-CO₂ gases
21 is the lack of agreement on base year emissions. This reflects a lack of knowledge or
22 agreement on how to represent emission-causing processes.

23 While the IS92 scenarios were designed as non-intervention reference cases, emission
24 estimates of the lowest scenario (IS92c) falls within the range of published policy scenarios.
25 Nevertheless, as a whole, the IS92 scenarios do not reflect the range of policy scenarios and
26 they should not be interpreted as policy scenarios.

27 At the regional level there are several instances in which the IS92 scenarios do not
28 suitably reflect the range of views represented by other scenarios. Notably, future emissions
29 in Central and Eastern Europe and the Former USSR (EEFSU) are higher than in more recent
30 scenario studies that take the effects of economic crisis into account. In addition, the IS92
31 base year (1990) estimate of CO₂ emissions is about 30 percent higher than the latest
32 estimate. For the USA, the IS92 scenarios span a lower range than the full spectrum of
33 scenarios available in the literature.

34 The analysis of energy scenarios does not provide any evidence that IS92a or any
35 other individual IS92 scenario is a "medium" or "central" case. IS92a in particular sometimes
36 covers well the "middle of the road" of alternative regional scenarios, but often is above or
37 below the median of other scenarios.

38 The IS92 scenarios are not always representative of the range of driving forces such
39 as population and economic development, energy intensity, and carbon intensity, found in
40 published *regional* scenarios. In some cases the IS92 scenarios span a much narrower range
41 than other scenarios. For example, the IS92 scenarios assume a much narrower range of
42 energy intensities in the USA and China plus Centrally Planned Asia, than the range of
43 published scenarios. In other cases, the IS92 scenarios fall outside the range of other
44 scenarios. An example of this is the GNP growth rate assumed in IS92e which is higher for
45 the USA and China plus Centrally Planned Asia, than any other scenario. The trend of
46 driving forces in the IS92 scenarios also deviates in some circumstances from the other

published scenarios, as in the case of Africa where the IS92 scenarios assume increasing energy intensity up to year 2020, and all but one other scenario assumes a downward trend. Thus the IS92 scenarios only partly reflect the range of regional views expressed in the published scenarios. It is important to note that regional perspectives can be included in global scenarios through a decentralized approach to scenario-building which includes the participation of scientists and policy makers familiar with national and regional circumstances. Examples of this are the scenario-building exercises sponsored by the World Energy Council, the Energy Modeling Forum, the International Energy Workshop, UNEP, and the CHALLENGE project of IIASA.

6.4 Comparison of Scenarios Related to Land Use

Very few scenarios of emissions related to land use and agriculture are available for comparison to the IS92 scenarios. However, in contrast to the energy-related scenarios, most of these scenarios include a range of greenhouse gas emissions rather than just CO₂. The scenarios reviewed in this section include:

- The previously described IS92 scenarios plus two sensitivity scenarios included in the IS92 document -- S1 (high estimates of deforestation and carbon content of vegetation) and S4 (low estimates of deforestation, high forestation rate).

- The U.S. Environmental Protection Agency (EPA, 1990) -- "Slowly Changing World" (SCW), "Rapidly Changing World" (RCW) and two "Stabilizing Policies" scenarios (SCWP and RCWP). These scenarios were developed from the Atmospheric Stabilization Framework (ASF) of the EPA which includes calculations from the global food system model, the "Basic Linked System" (BLS), developed at the International Institute for Applied Systems Analysis (IIASA),

- The IMAGE 2.0 "Conventional Wisdom" (CW) scenario (Alcamo et al., 1994.)

- The Asian Pacific Integrated Model (AIM) (Morita, et. al, 1994).

- The three scenarios (H1 - H3) developed by Houghton (1991).

The scenarios S4, SCWP, and H3 assume policy intervention to reduce emissions, whereas the other scenarios can be considered "non-intervention" reference scenarios.

Because of space limitations, this section focuses only on emissions of CO₂ from deforestation, CH₄ from wetland rice fields and enteric fermentation, and N₂O from soils underlying fertilized agricultural areas and soils underlying natural vegetation. These categories were selected because they illustrate the sensitivity of emission estimates to differences in input assumptions regarding agricultural variables. The scenario comparisons focus on both global estimates and regional estimates from Latin America, Africa and Asia. These regions are of particular interest because they are experiencing significant changes in the driving forces of land use emissions (e.g. agricultural expansion, agricultural productivity, deforestation, and population growth). The scenarios of CO₂ from deforestation include the fluxes of carbon resulting from changes in the area of forests, but not climatic feedbacks to the terrestrial carbon cycle.

For reference, Table 6.9 presents an overview of how each of the scenarios takes into account driving forces of land use emissions. Table 6.10 summarizes other key assumptions of the scenarios.

6.4.1 Results from CO₂ Global Scenarios

Before discussing the differences in estimates of future emissions, it should be noted that the scenarios also disagree on base year (1990) emissions, with estimates ranging from 0.7 to 2.5 Pg C a⁻¹. This reflects the lack of knowledge or agreement on how to represent the processes leading to CO₂ fluxes between the biosphere and atmosphere. Earlier it was noted that a similar situation exists for regional-scale energy-related emissions.

Most "non-intervention" scenarios show an upward trend until about year 2020, followed by a gradual decline (Figure 6.12). In comparison to energy-related scenarios which diverge up to year 2100, land use emissions show their greatest absolute differences around the middle of the next century (with a maximum range of about 0.8 to 4.8 Pg C a⁻¹), and then converge towards zero at the end of the century. Emissions decrease because either the driving forces of deforestation stabilize or because forests are depleted.

The lower scenarios are IS92 a,b,e, AIM, and CW, and they have very similar decreasing global trends after 2010. Both H1 and SCW increase sharply until year 2050, but their magnitude of emissions is very different because they begin with very different base year emissions. The IS92 a,b,e scenarios show a net uptake of carbon from 2090 to 2100, resulting from assumptions about forest plantations in Africa and Asia. In most of the scenarios, the release of carbon by forest biomass burning greatly exceeds the amount of carbon taken up in plantations.

The range of cumulative emissions (of non-intervention scenarios) over the period 1990 to 2100 is 80 to 320 Pg C, indicating that the biosphere could continue to be a significant source of CO₂ in the atmosphere in the next century (Figure 6.13). The range in estimates of cumulative emissions (factor of four) is smaller than the maximum range of annual emissions (factor of six). This was also found to be the case for energy-related emissions. As noted earlier, this smaller gap between scenarios for cumulative emissions is significant from the point of view of climate impact analysis because of the lag time of build-up of CO₂ in the atmosphere.

Cumulative emissions of the intervention scenarios assume considerable forestation and result in a significant uptake of atmospheric CO₂ (30-150 Pg C).

The cumulative emissions of CO₂ from deforestation have an upper limit formed by the amount of carbon stored in the global terrestrial biosphere of about 600 Pg (Atjay, et al., 1979; Olson et al, 1983). According to the non-intervention scenarios reviewed in this chapter, deforestation in the next century may consume between 15 and 50% of the carbon stored in the global terrestrial biosphere.

Summing up the discussion of global CO₂ scenarios from land use, their emission estimates vary by a maximum of a factor of six in the mid 21st century, and then converge to zero towards the end of the century because the driving forces stabilize or forests are depleted. By comparison, the range of cumulative emissions is a factor of four. This is significant from the climate analysis point of view because of the lag time in the build-up of CO₂ in the atmosphere.

Table 6.9: Major driving forces for land cover/use change

Process	IS92 (IPCC)	SCW/RCW	CW (IMAGE 2.0)
Deforestation	Proportional to population increase, with a lag time of 25 years.	External scenario based on Terrestrial Carbon Model (Houghton et al., 1983) for tropics only. Deforestation is not a result of demand for agricultural products.	Forest clearing is result from change in demand for crop and animal products and industrial and fuelwood. The land's productivity as a function of climate and soil conditions is taken into account, as well as the effect of climatic change on productivity.
Demand for agricultural products	See SCW/RCW	Demand consists of human consumption, feed, seed, industrial usage and waste. Human consumption is based on past trends (reflecting income, habits, tastes). Income changes allow changes in consumption. The model allows changes in arable land and pastures. Technical progress is captured in yield functions for 9 commodity classes.	Demand is determined by population and income through elasticities. This affects the required areas of both arable land and grassland. Arable crops are divided into 9 classes of vegetable products and 5 classes of animal products.
Crop production	See SCW/RCW	Crop yields are function of fertilizer application. BLS extrapolates the trend in land use per capita from 2025-2050 to the period 2050-2100.	Crop yields change as a consequence of the additions of agricultural inputs and technological development.
Rice acreage	See SCW/RCW	Various methods, e.g. China: based on past trends; India, Indonesia, US: based on relative profitability of rice compared to other crops.	Rice acreage is determined from demand for rice, based on income elasticity. The increase in harvested area is the result of increases in irrigated rice only, with the 1990 dryland area remaining constant.
Animal production and numbers	See SCW/RCW	The production of animal products is function of feeding intensity. For most regions the number of animals is not calculated explicitly.	In period 1990-2025 the production per animal increases along with GNP/capita to 1990 OECD-Europe productivity as GNP reaches 1990 OECD-Europe level. For industrialized countries increase in productivity is 10%. In 2025-2050 the increase in productivity is 50% of that in 1990-2025, in 2050-2100 the increase is zero.
Fertilizer use	Pre-specified. Scenario from Pepper et al. (1992).	Fertilizer use is explicit variable in most parts, except in regional models in BLS. In regional models agricultural production determines fertilizer use.	Fertilizer use is pre-specified, not a model result. Scenario for fertilizer use is from IS92a (Pepper et al., 1992).

6.4.2 Results from CO₂ Regional Scenarios

The available regional scenarios of CO₂ (IS92, SCW and CW) show considerable differences (Figures 6.14a to 6.16a). The CW scenario for Africa greatly exceeds the other scenarios until about 2060, when Africa forests are depleted according to the scenario (Figure 6.14). After 2050, IS92 a,b,e show a net uptake in Africa resulting from forest plantations.

In Latin America, the SCW scenario is much higher than the others because it assumes a higher forest exploitation rate, while CW is much lower than the others because it computes a stabilization of driving forces that have led to deforestation (Figure 6.15).

Table 6.10. Assumptions of land use scenarios of emissions

Source	IS92a	SCW/RCW	CW
CO ₂ from deforestation and reforestation	Low estimates of biomass based on OECD (1991)	Based on clearing rates and on low biomass estimates in vegetation and soils from Houghton (1991). High and low biomass values are specified for 6 types of forest (disturbed and undisturbed moist, seasonal and dry forests) and for 3 continents. The SCW scenario uses the low biomass estimates.	Carbon contents are result of soil and climate (BIOME model and Klein-Goldewijk et al. (1993).
CH ₄ from wet rice cultivation	38 g m ² a ⁻¹	75 g m ² a ⁻¹	38 g m ² a ⁻¹
CH ₄ from animals	Crutzen et al. (1986); Lerner et al. (1988). Emissions per unit of product decrease with productivity.	Crutzen et al. (1986); Lerner et al. (1988). Emissions per unit of product decrease with productivity.	Gibbs and Leng (1993); Crutzen et al. (1986). Emissions per unit of product decrease with productivity.
CH ₄ from animal waste	1990 emission of 26 Tg a ⁻¹ (source not specified)	Not included in calculations	Based on Gibbs and Woodbury (1993), giving total of ~13 Tg a ⁻¹ for 1990.
Biomass burning emissions (CH ₄ , CO, NOx, N ₂ O, VOC)	Crutzen and Andreae (1990)	Various literature sources (Cicerone and oremland, 1988; Seiler and Crutzen, 1980 and other references)	Crutzen and Andreae (1990)
N ₂ O from fertilizer and animal excreta;	Fertilizer induced emission of 2.6% of applied mineral fertilizer-N. Background and animal excreta not considered.	Fertilizer induced emission of 2.5% of applied mineral fertilizer-N. Background and animal excreta not considered.	Fertilizer induced emission 1% of applied mineral N and 1% of N in animal excreta, based on Bouwman et al. (in prep.). Background emission from arable lands and pastures are based on climate and NPP.
N ₂ O from natural ecosystems	6.1 Tg N a ⁻¹ , constant in time.	6.0 Tg N a ⁻¹ , constant in time.	Depending on temperature, precipitation, NPP (Based on Bouwman et al. (1993).
N ₂ O from gain in agricultural land	Luizao et al. (1989) for current flux of 0.8 Tg N a ⁻¹ .	Bolle et al. (1986) for current flux of 0.4 Tg a ⁻¹ .	Modelled, based on Keller et al. (1993) and Bouwman et al. (in prep).
Other sources	Calculated as complement to assumed global source	Calculated as complement to assumed global source	Calculated as complement to assumed global source.

For Asia, the SCW and CW scenarios show the largest differences to the IS92 and AIM scenarios (Figure 6.16). Part of the differences may be caused by differences in the definition of regions. For example, the deforestation estimates in IS92 and SCW do not include China, although computed deforestation in the CW scenario which does include China is considerable. For Asia, the CW scenario peaks around year 2000, mainly caused by high deforestation rates in India. Both the IS92 and CW scenarios assume that wood from forest clearings are not burned in China and Centrally-Planned Asian countries. Hence deforestation in this part of Asia is assumed to result in a low, long-term flux of carbon from enhanced soil respiration, rather than a higher short-term flux due to wood burning of cleared forests. Hence, although the global results for CO₂ fluxes are consistent, the regional results show a much greater disagreement.

Summing up the discussion of regional CO₂ scenarios from land use, the differences in their emission estimates are quite large. However, some of these regional differences apparently cancel each other so that differences in global results of the scenarios are not as great.

6.4.3 Factors Affecting CO₂ Emissions from Deforestation

The main factors used to estimate CO₂ emissions from deforestation are: (i) the rate of deforestation, (ii) the carbon content of vegetation, and (iii) the allocation of the cleared biomass to different carbon pools on the deforested land. The last factor will influence the timing of the release of CO₂, but will have only a small effect on the cumulative emissions. Hence, the following sections will only discuss the first two factors. Table 6.9 describes the driving force assumptions made in various scenarios to compute CO₂ emissions from land use. Table 6.10 makes a qualitative comparison of the scenario assumptions of deforestation, reforestation, and carbon content.

6.4.3.1 Deforestation Rates

The IS92 and CW scenarios have similar global average deforestation rates, but differ within regions (Figures 6.14b, 6.15b, 6.16b). The IS92 scenarios for Africa increase up to 2020, and decline slowly afterwards (Figure 6.14b). The CW scenario increases more quickly than IS92, but also peaks around 2020. Afterwards the rate of deforestation declines at a faster rate than the IS92 scenarios, reaching zero around 2070 when all African forests are depleted. In the meantime, the AIM scenario peaks somewhat earlier than the other two scenarios, and also maintains a lower rate of deforestation throughout much of the period.

For Latin America the deforestation rate of the IS92 scenarios gradually decreases towards 2100 (Figure 6.15b). Meanwhile, the net rate of the CW scenario decreases much more rapidly, reaching zero in 2005. Afterwards, there is a net forestation of abandoned agricultural and rangeland until 2050 when net forestation also reaches zero. The AIM scenario parallels the trend of the IS92 scenarios, but at a lower rate.

Deforestation in Asia slowly decreases in the IS92 scenarios, reaching near zero in 2100 (Figure 6.16b). Again the AIM scenario follows the trend of the IS92 scenarios, but with a lower deforestation rate. The CW scenario is very different from these scenarios, peaking around the year 2000 in China and India, and then rapidly decreasing by 2045 as forests are depleted.

Most scenarios base their deforestation rates on population estimates, under the assumption that population is related to demand for agricultural and forestry products which, in turn, leads to deforestation. The population scenarios used in the IS92 and CW scenarios (World Bank, 1990), SCW and RCW (USBC, 1987), AIM (UN, 1992) are only slightly different in their estimates of population trends to the year 2100. These small differences cannot explain the significant differences in deforestation rates between some of the published scenarios. Houghton (1991) does not report the population estimates used for scenarios H1 and H2.

The IS92 and AIM scenarios set deforestation rates proportional to population, with a 25 year time lag. Hence, as population growth declines (which it ultimately does according to the assumed population scenarios), deforestation rates also decline.

The SCW and H1 scenarios have similar emission trends, and it is presumed that their underlying deforestation assumptions are similar. Deforestation in the SCW scenario is a

function of population growth, while in H1 it is extrapolated from historical trends of tropical deforestation in FAO/UNEP (1991).

As compared to the SCW and H1 scenarios, the deforestation rates of the RCW and H2 scenarios are based on higher rates of agricultural productivity, which leads to lower rates of agricultural expansion and deforestation. The CO₂ emissions estimated by the two scenarios differ because of different assumptions about carbon content of vegetation rather than different assumed deforestation rates.

Deforestation rates are computed indirectly in the CW scenario: population and GNP scenarios are used to compute regional agricultural demands which are then used to estimate the expansion or abandonment of agricultural and rangeland on a geographically-detailed basis for the whole world. Expansion of land for crops or livestock leads to a certain amount of forest clearing from which a deforestation rate can be derived.

Box 3. Uncertainties in Estimating CO₂ from Deforestation: An Indonesian Example

Country estimates help illuminate the uncertainties in estimating the driving forces of CO₂ emissions from deforestation. The report JEE(1993) estimates an Indonesian deforestation rate of 1.3 Mha a⁻¹ for the period 1982-1990. Deforestation was attributed to a combination of expansion of agricultural land, infrastructure, and urban centers; as well as shifting cultivation, forest fires, and logging. The CO₂ release to the atmosphere from deforestation was estimated by JEE(1993) to be 45-90 t C ha⁻¹ a⁻¹ from biomass and 1.4 t C ha⁻¹ a⁻¹ from soil decomposition which adds up to a flux of 60 to 124 Tg C a⁻¹ (1989/90) from Indonesia. This can be compared to Houghton's estimate of 192 t C a⁻¹ (Houghton, 1991) which is based on assumptions about the carbon content of different types of vegetation.

The carbon uptake of vegetation was estimated by JEE (1993) to be around 103 to 224 Tg C a⁻¹ based on an annual carbon uptake of 3.0-6.6 t C ha⁻¹ a⁻¹ for 17 Mha of forest fallow and 4 Mha of forest plantations. This is about 20% of the total Indonesian forest area estimated by Myers (1991).

6.4.3.2 Carbon Content of Vegetation

Another major factor influencing the range of CO₂ emission estimates is the uncertainty of carbon content of vegetation. Pepper et al. (1992) and EPA (1990) point out the sensitivity of the IS92 and SCW and RCW scenarios to this uncertainty (See also Box 3).

There are two different methods to estimate the carbon content of vegetation. Higher estimates are obtained by destructive sampling of biomass, and lower values are obtained by estimating the content of wood volumes. The mean carbon content of all tropical forests is about 65% higher for destructive sampling than for wood volume based estimates (Houghton, 1991). The scenarios reviewed above use different premises for their estimates of carbon content of vegetation. The IS92 scenarios use OECD (1991), which are mid-ranges of values based on estimates of wood volumes used by Houghton (1991). The H1 to H3 scenarios are based on the mean of the two methods --destructive sampling and estimation from wood volumes; while the SCW, RCW, SCWP, and RCWP scenarios are identical to the low estimates of Houghton (1991). The continental mean carbon content of vegetation in CW is similar to the low estimates in the IS92, RCW and SCW scenarios. However, unlike the other scenarios, carbon content of vegetation in the CW scenario changes with time in accordance with changes in climate and atmospheric CO₂ concentration. Hence, the scenarios reviewed

contain various combinations of assumptions for deforestation rate and carbon content.

Summing up the discussion of factors influencing the estimation of CO₂ emissions from land use -- there are comparatively few studies to compare, and their assumptions about deforestation rates vary considerably. However, the scenarios agree that deforestation will diminish by the end of the 21st century because of stabilization of the driving forces of deforestation or the depletion of forests. The carbon content of vegetation is another important assumption in estimating CO₂ emissions, and the various scenarios use a wide range of estimates for this variable.

6.4.4 Results from Global Scenarios of non-CO₂ Greenhouse Gases

The scenarios IS92, SCW and CW include global and regional estimates of emissions other than CO₂. This section highlights global scenarios of some of the more important emission categories of these gases.

For CH₄ from rice fields, the SCW scenario assumes a base year (1985) emissions that is twice as large as the IS92 and CW scenarios (Table 6.11). However, the temporal trend of the SCW scenario is close to that of the IS92 scenario in that it increases until around the middle of next century, and declines slowly afterwards. The CW scenario, by comparison, declines until around 2025, and then slightly increases to the end of the century. These trends reflect the harvested area of wetland rice assumed in the scenarios. This issue will be discussed later in this chapter.

The scenarios for CH₄ from enteric fermentation agree on base year (1985) emissions and trends up to 2000 (Table 6.12). Afterwards, emission estimates of the IS92 and SCW scenarios increase up to the end of the century, although the SCW does so at a slower rate. By contrast, the CW emissions peak around 2050 and decline afterwards. The lower emissions of the CW scenario result from its assumptions about increases in the meat productivity of animals which leads to estimates of lower numbers of animals than the other scenarios.

The various scenarios of N₂O emissions from soils of natural vegetation (not shown) differ greatly. The IS92, RCW, and SCW scenarios have constant global emissions, while the CW scenario slowly increases. Part of the difference in scenarios arises because the CW scenario takes into account climatic feedback to N₂O emissions. By comparison, scenarios of N₂O emissions from soils of fertilized agricultural areas do not vary as much because they are all based on the same global scenario of fertilizer use. In this case the difference between scenarios stems from differences in assumed emission factors.

6.4.5 Results from Regional Scenarios of non-CO₂ Greenhouse Gases

With regards to CH₄ from rice production, this paragraph focuses on scenario results for Asia where about 90% of the world's rice is produced. The three available scenarios differ very considerably. Base year (1985) emissions of SCW are nearly twice as high as the CW and IS92 scenarios (Table 6.11). The IS92 scenarios show a 24 Tg CH₄ a⁻¹ increase by year 2100, as compared to a 52 Tg CH₄ a⁻¹ increase for the SCW scenario, and a 4 Tg CH₄ a⁻¹ decrease in the CW scenario. However, both the SCW and IS92 scenarios project an increase of about 50% in CH₄ emissions, because of their identical assumptions about the increase in harvested rice area (Table 6.11). The IS92 scenarios indicate a nearly constant emissions levels for China plus Centrally Planned Asian countries (not shown), while the CW scenario estimates a reduction by a factor of 2 caused by a major increase in rice yields per hectare. Emissions

Table 6.11: Emissions of CH₄ from wetland rice cultivation in Tg CH₄ a⁻¹

	1985	1990	2000	2010	2020	2025	2050	2075	2100
SCW									
Africa	2.6		3.9			5.5	6.6	7.6	7.8
Asia	96.0		110.0			131.6	148.5	155.3	148.1
LA	6.0		6.5			7.1	6.8	6.8	6.5
World	109		125			149	165	176	169
CW									
Africa	1.2	1.4	1.8	2.4	3.5	4.2	8.2	11.9	15.7
Asia	53.8	54.3	46.8	40.7	38.5	38.5	39.4	38.3	37.7
LA	2.5	2.4	2.6	2.6	2.5	2.4	2.5	2.7	3.0
World	58	59	53	48	46	47	52	55	54
IS92 a,b,e									
Africa	1.4	1.6	2.0	2.5	2.8	2.9	3.4	3.9	4.1
Asia	50.5	52.9	58.0	62.9	66.7	69.2	78.2	76.3	74.2
LA	3.1	3.1	3.4	3.7	3.7	3.7	3.4	3.3	3.2
World	58	60	66	69	76	78	87	86	84

Table 6.12: Emissions of CH₄ from enteric fermentation in Tg CH₄ a⁻¹

	1985	1990	2000	2010	2020	2025	2050	2075	2100
SCW									
World	75		94			125	151	172	179
CW									
Africa	8.1	8.5	11.2	14.9	21.5	25.4	40.5	43.5	47.5
Asia	22.8	24.1	38.9	53.6	68.0	75.1	82.3	69.9	63.1
CP Asia	6.7	7.2	16.1	24.2	31.4	34.8	31.1	27.5	24.8
LA	8.1	17.7	19.5	19.0	18.5	18.2	13.8	9.7	7.5
USA	5.8	5.6	4.3	3.2	3.0	2.9	2.8	2.8	2.2
World	75	79	96	112	131	142	161	147	142
IS92 a,b,e									
Africa	8.6	9.8	13.2	16.5	20.2	22.6	33.1	42.4	48.1
Asia	22.0	23.8	28.6	34.1	40.3	43.7	61.1	66.5	69.9
CP Asia	4.9	5.2	5.7	6.2	6.8	7.0	8.6	8.5	8.7
LA	16.0	18.0	22.0	26.0	30.0	32.0	40.0	42.0	43.0
USA	7.1	7.8	8.8	8.9	9.3	9.2	6.6	6.0	6.0
World	77	84	99	114	129	138	173	188	198

of CH₄ from rice fields in India (not shown) also decrease by 20% in the CW scenario by 2100 because of faster increases in rice yields per unit area than in rice demand.

With regards to estimates of CH₄ emissions from enteric fermentation, there are no large differences between the IS92, SCW, and CW scenarios for Africa. Estimates for Asia as a whole are also close, but within Asia there are large differences (Table 6.12). For example, in the China plus Centrally Planned Asia, the IS92 scenario has low and nearly constant emissions as compared to the CW scenario which has a rapid increase between 1985 and 2025, and a decline of 30% between 2025 and 2100.

The IS92 scenarios of Latin America for CH₄ from enteric fermentation show a large increase from 16 Tg to 43 Tg CH₄ between 1985 and 2100, whereas the CW scenario gives a doubling in emissions between 1990 and 2025, and a decline thereafter (Table 6.12).

Regional results for N₂O from soils underlying natural vegetation are only provided by the CW scenario, which estimates that increases will be most important in temperate climates because of the importance of climate feedbacks there.

With regards to N₂O from fertilized soils -- different regional assumptions of fertilizer use lead to different estimates of N₂O emissions. For example, the growth in fertilizer use and associated N₂O loss for Africa is higher in IS92 a,b,e than in CW. The increase in fertilizer-related N₂O is similar for Asia as a whole, but different for e.g. Centrally Planned Asian countries. For Latin America the growth of N₂O emission from N-fertilizer is faster in CW than in IS92 a,b,e.

6.4.6 Factors Affecting non-CO₂ Emissions from Land Use

For reference, the main driving forces of non-CO₂ emissions from land use are reviewed in Table 6.9 and key assumptions of the scenarios in Table 6.10.

6.4.6.1 Factors Affecting CH₄ From Rice Production

This section discusses the assumptions of different scenarios leading to estimates of CH₄ emissions from rice fields. The main factors influencing the estimation of emissions are the assumed rate of CH₄ emissions per unit area of rice field, and the total area of rice fields. The area of rice fields is in turn, influenced by the assumed rice yield per ha. The scenarios reviewed in this report all assume that the emission rate of CH₄ does not change with time.

The RCW and SCW scenarios give emission rates for wetland rice that are twice as high as the value used in the IS92 scenarios. The CW scenario uses the same wetlands emission rate as in the IS92 scenarios, but unlike the IS92 scenarios, distinguishes between wetland and dryland rice areas. This contributes to the difference between the IS92 and CW scenarios. In addition, the IS92 scenarios estimate the area of rice fields based on *a priori* assumptions about per capita rice consumption and rice yield per ha, whereas the estimate of rice area in the CW scenarios is based on economic and technological development. The rice yields of the IS92 scenarios are similar to those of the CW and SCW scenarios for South and Southeast Asia (Figure 6.17b), but are lower than those of the CW scenario for China and Centrally Planned Asia (Figure 6.17a). The higher yields in the CW scenario lead to smaller areas of rice fields as compared to the IS92 scenarios, and hence to lower CH₄ emission estimates. In India, the CW scenario shows that rice yield improvements exceed the increase in rice demand up to 2025, leading to a decrease in rice area and CH₄ emissions. After 2025 demand exceeds the yield improvement, and both rice area and CH₄ emissions increase.

1 Emissions in the IS92 scenarios are relatively constant up to 2100.

2 The global yield increase of rice is assumed to be about 0.9% a⁻¹ in the IS92, SCW
3 and RCW scenarios for the period 1990-2010. FAO (1993) assumes a global yield increase
4 of 1.5% a⁻¹ and increase in harvested area of 0.5% a⁻¹ for the period 1990-2010 leading to a
5 rise in production of 2% a⁻¹. The total yield increase over the period is about 35%. This is
6 even more optimistic than the yield increase of 25% for Asia assumed by CW, and
7 substantially different from the IS92, SCW, and RCW scenarios.

8 National projections can be used to examine the assumptions for different regions. For
9 example, in Indonesia a number of different scenarios were developed to analyze different
10 combinations of development in rice yields and harvested and planted rice area (DOAI, 1993).
11 The highest yield increase was 1.5% a⁻¹, with an increase in harvested area of 0.6% a⁻¹ to
12 arrive at a 2.2% a⁻¹ growth in rice production. The same 2.2% a⁻¹ rise in production could also
13 be achieved with a yield increase of 0.9% a⁻¹ combined with an increase of 1.2% a⁻¹ in
14 harvested area. The latter scenario was based on historical increases in rice yield and is much
15 less optimistic about rice yields than FAO (1993), IPCC IS92 scenarios, CW and RCW and
16 SCW. This Indonesian example shows the important effect of assumptions about rice yields
17 on the development of harvested area.

18 19 6.4.6.2 Factors Affecting CH₄ from Enteric Fermentation

20 Estimates of CH₄ emissions from enteric fermentation depend on assumptions about the
21 number of animals, and this in turn depends on the size of the demand for meat and dairy
22 products and the amount of meat and dairy products produced by each animal (animal
23 productivity).

24 The major difference between the IS92 and CW scenarios is the estimation of demand
25 for meat and dairy products. This depends on demographic, economic and technological
26 factors in CW, and on *a priori* assumptions in the IS92 scenarios. Therefore, in regions with
27 fast economic growth, the demand for these products increases much faster in CW than in the
28 IS92 scenarios.

29 Of the scenarios reviewed, only the CW scenario makes explicit assumptions about
30 meat productivity. Over the period 1990-2010, the CW scenario assumes a 0.2 to 1.5% a⁻¹
31 increase in developing regions, whereas FAO (1993) assumes a much higher 0.9 to 1.9% a⁻¹
32 for the same period. Scenarios of animal populations are linked to these productivity
33 assumptions. For the period 1990-2010 the CW scenario shows an increase in the number of
34 cattle by a factor of 1.9 for Africa, 2.2 for the Middle East, 5.6 for China, 1.2 for India and
35 1.3 for Latin America. The corresponding estimates from FAO (1993) are much lower,
36 namely, 1.3 for Africa, 1.4 for Middle East, 2.3 for East Asia (including China), 1.2 for South
37 Asia (including India) and 1.1 for latin America.

38 39 6.4.6.3 Factors Affecting N₂O from Fertilized Agricultural Soils

40 The amount of N₂O from fertilized soils depends on the amount of fertilizer used and the N₂O
41 loss rate from soil. It was already pointed out that the scenarios reviewed here assume the
42 same amount of future fertilizer use. Hence most differences between scenarios arise from
43 different assumptions about N₂O loss rates from soils.

44 The assumed growth of fertilizer up to 2010 is substantially lower than given in FAO
45 (1993). For the period 1990-2010, FAO assumes a 3.3 to 4.8% a⁻¹ growth in fertilizer use in
46 Africa, Latin America and Asia.

1 *Summing up the discussion of factors influencing the emissions of non-CO₂ gases from land*
2 *use -- The scenarios reviewed take a great variety of different approaches in estimating future*
3 *emissions. This reflects the lack of knowledge or agreement on how to represent emission-*
4 *generating processes. In general, the IS92 scenarios do not cover the range of input*
5 *assumptions found in other published scenarios.*

6.4.7 Discussion

9 Different clusters of scenarios for CO₂ emissions from deforestation are distinguishable.
10 Starting with global scenarios, the IS92 and AIM scenarios make similar assumptions about
11 the relationship between population growth and emissions. Consequently, as population
12 growth slows, they estimate similar downward trends in emissions. The CW scenario takes
13 into account growth of population, GNP, as well as technological development and other
14 factors, and calculates a global emissions trend close to the IS92 and AIM scenarios. These
15 scenarios are also in the lower range of non-intervention scenarios. The remaining non-
16 intervention scenarios, SCW, RCW, H1, and H2, extrapolate past trends in deforestation and
17 estimate much higher emission rates than the other scenarios.

18 For regional scenarios, the CW differed greatly from the IS92 and AIM scenarios
19 because of differences in methods for estimating future trends in deforestation. Although
20 nearly all scenarios relate the deforestation rate only to population growth, it is known that
21 deforestation is more precisely related to pressure for agricultural land, wood products,
22 settlement policy, and other socio-economic factors (Turner, et al. 1993). Accounting for these
23 factors would permit the construction of more diverse scenarios of CO₂ emissions.

24 Much of the variation between scenarios on both the global and regional basis can be
25 attributed to different estimates of base year emissions. This indicates the lack of scientific
26 agreement on the processes leading to CO₂ fluxes from deforestation. Another important
27 source of variation is differing estimates of carbon content of vegetation. For example, the
28 SCW and H1 scenarios differ only because of their different assumptions of carbon content
29 of forests.

30 The scenarios for CH₄ emissions from rice fields and enteric fermentation are sensitive
31 to assumptions about future technological improvement of rice and animal productivity.
32 Estimates of the different scenarios disagree with FAO (1993) and perhaps should be re-
33 evaluated. Another source of uncertainty for CH₄ estimates from rice fields is the rate of
34 emissions per unit area of rice field. Although the scenarios surveyed in this report assumed
35 a global, constant emission factor, the rate of emissions is known to depend on site
36 conditions, rice variety, and crop management. Some of this knowledge should be built into
37 new scenarios.

38 A drawback of the IS92 and other scenarios is that they do not take into account
39 important climatic and atmospheric feedbacks to land use emissions (e.g., N₂O from soils and
40 CO₂ from soil respiration). The only scenario to do so is the CW scenario, although there is
41 of course great uncertainty in its treatment of these feedbacks.

42 From the land use emissions perspective, the IS92 scenarios are on the low side of the
43 wide range of global scenarios for CO₂ from deforestation, and overlap with the few regional
44 scenarios that are available. They also partly overlap with the few scenarios available for N₂O
45 and CH₄ emissions. In addition, the IS92 scenarios cover most of the greenhouse gases
46 originating from land use and agriculture, as well as precursors of ozone and sulfate aerosol.
47 Emissions are reported for four world regions and by source and sector.

With regards to reproducibility of the IS92 land use scenarios -- their documentation of certain land use assumptions is not quite adequate to reproduce the scenarios. For example, it would be helpful to have a more detailed description of the assumptions about forestation, rice production, and animal production.

6.5 Evaluation of IS92 Scenarios

In this section, we evaluate the IS92 scenarios in light of the requirements for scenarios laid out in Section 6.1. It should again be emphasized that the scope of this evaluation was greatly limited by time constraints. Hence, many factors of relevance to the evaluation have been only briefly considered or omitted. Also, in fairness, it is important to note that we have not had time to judge other scenarios by the criteria with which we judge the IS92 scenarios. Therefore the reader should be aware that any shortcomings of the IS92 scenarios identified in this evaluation could also apply to other published scenarios.

As a method for judging whether the IS92 scenarios comply with requirements in Section 6.1, they have been compared to other scenarios. This comparison does not answer all questions about requirements, but provides important information about the relative position of the IS92 scenarios with regards to other work in the scientific community. In this chapter we first review the results of this comparison, and then briefly discuss the economic and population assumptions of the scenarios. We then address the uses and limitations of the IS92 scenarios and the question of new scenarios.

6.5.1 Energy Related Scenarios - How Different Are Their Results?

6.5.1.1 Global Results

By far the largest number of published scenarios concern global emissions of CO₂ stemming from energy and industry. Consequently much of the comparison of scenarios focuses on this type of scenario. The following can be said of the results of these scenarios:

- The set of global CO₂ scenarios examined have hugely varying pathways that diverge with time, although nearly all show an upward trend.
- The range of estimates is not so substantial over the medium-term (up to year 2025), ranging from 6.7 to 19.8 Pg C a⁻¹ (or alternatively Gt C a⁻¹). However, over the long-term (up to 2100) the range of estimates widens to a factor of 50, from 1.2 to 60.0 Pg C a⁻¹.
- Although there is a huge range in emission estimates, this range can be explained mostly by the input assumptions of the scenarios, particularly economic growth or activity, population growth, and energy and carbon intensity. Another significant factor is the uncertainty of the models or other methods used to compute the scenarios.
- The time pathways of the six IS92 scenarios fall within the majority of published scenarios, ranging in the year 2100 from 4.6 to 35.8 Pg C a⁻¹.
- Three published uncertainty studies of future CO₂ global emissions also reported an enormous range of future estimates, from 2 to 87 Pg C a⁻¹ for year 2100 (for the 5th and 95th percentiles of the uncertainty distributions). The IS92 scenarios also fall within the range of these estimates.
- The cumulative emissions of the published scenarios over the period 1990 to 2100 have a considerably smaller range, spanning from 492 to 3447 Gt C (a factor of 7). Cumulative

emissions are especially important from the climate impact perspective because of the lag time of build-up of CO₂ in the atmosphere. This implies that the range of estimates of future emissions are less uncertain for climate impact analysis than for other uses of scenarios.

As compared to CO₂, there are far fewer published scenarios of non-CO₂ emissions. For these scenarios an additional source of uncertainty is important, namely, the uncertainty of *current* emission estimates. This means that non-CO₂ scenarios have an overall lower reliability than CO₂ scenarios. The results of the IS92 scenarios vary by a factor of 6 to 7 for CH₄ and N₂O in year 2100, and overlap with the other few published scenarios.

6.5.1.2 Regional Results

As for *regional* CO₂ emission scenarios, there are far fewer regional estimates than global estimates, with the exception of the USA. The following can be said of the few published scenarios of this type:

- The range of results is about the same as that of global scenarios.
- For the region Eastern Europe and former Soviet Union, the IS92 scenarios have a higher trend than recently published scenarios that take into account the change in economic activity in these regions.
- The range of IS92 scenarios are on the low side of the range of published reference estimates for the USA.

6.5.2 Energy Related Scenarios - How Do Their Inputs Compare ?

Both the IS92 scenarios and published scenarios rely on large numbers of input assumptions. It was outside the scope of this evaluation to assess the differences between all of these assumptions. Therefore the evaluation focuses on differences between key inputs common to most scenarios, namely, population growth, economic growth (although economic growth is a calculated variable in some scenarios), energy intensity (the amount of primary energy used per unit GNP), and carbon intensity (the amount of carbon emitted per unit GNP). Energy intensity is input to some scenarios, and in others it is derived from scenarios results. Carbon intensity is always derived from scenario results.

- All scenarios show a downward trend of energy intensity. The energy intensity of the IS92 scenarios overlaps with other scenarios but is partly outside their range.
- Carbon intensities in the published scenarios both decreased and increased, whereas in the IS92 scenarios carbon intensity always declines.
- Assumed changes in energy and carbon intensity have an important influence on estimates of emissions, especially in the second half of next century.
- In general, the input assumptions of the IS92 scenarios are fairly representative of published *global* scenarios, but not of published *regional* scenarios. For example, the IS92 scenarios span a much smaller range of assumptions of future energy intensity for China and the USA than the set of published scenarios. Hence the IS92 scenarios only represent part of the range of regional perspectives contained in the published scenarios.

6.5.3 Land Use Related Scenarios - How Different Are Their Results?

6.5.3.1 Global Results

Scenarios related to global land use emissions are much fewer in number than those of the energy system. As with energy-related emissions, global estimates are more common in the

literature than regional estimates. The following can be said about global CO₂ scenarios related to land use:

- The time paths of published non-intervention scenarios vary considerably, with a maximum difference of 0.8 to 4.8 Pg C a⁻¹, a factor of six. However, in contrast to energy-related emissions which diverge with time, these scenarios deviate most at mid-century and then converge to zero (by 2100, their range is from 0.0 to 0.8 Pg C a⁻¹). This is because by around 2050 the driving forces of deforestation stabilize or because forests are depleted.
- The IS92 scenarios fall within the lower range of other published global CO₂ scenarios.
- As with energy-related emissions, the range of cumulative emissions over the period 1990 to 2100 (80 to 320 Pg C for non-intervention scenarios) is considerably smaller than the range of annual emission estimates for year 2100. Above it was noted that this is significant from the point of view of climate impact analysis. Cumulative emissions have an upper limit given by the maximum available amount of terrestrial biomass that could be oxidized, i.e. around 600 Pg C. In contrast, there is no similar upper limit to energy-related emissions foreseen in the next century.

6.5.3.2 Regional Results

With regards to the few published *regional* land use scenarios of CO₂ and other greenhouse gases, there are very considerable differences between the scenarios; the IS92 scenarios sometimes fall within the range of other scenarios and sometimes outside. The range of emission estimates is about the same for regional scenarios as it is for global scenarios, and the scenarios converge in a similar way by the year 2100.

6.5.4 Land Use Related Scenarios - How Do Their Inputs Compare?

- The assumed rate of deforestation is the most important factor influencing emissions of CO₂ related to land use. Most scenarios make very simple assumptions about the driving forces of deforestation, although some scenarios are based on models that simulate land conversion. The different ways of representing deforestation lead to different estimates of deforestation rates, although the published scenarios agree that forest clearing will diminish by 2100 for the reasons cited above.
- Assumptions about carbon content of vegetation also strongly influence estimates of CO₂ emissions.
- In general, estimates of *current* land use emissions are more uncertain than estimates of current energy-related emissions. As a result, land use scenarios have different estimates for base year emissions, and this leads to greater differences between scenarios in their future estimates of emissions.
- Scenario results also differ from one another because the scenarios use very different methods to describe the land use processes that generate emissions. This reflects the lack of knowledge or agreement on how to represent these processes.
- The IS92 scenarios do not take into account the feedback of climate to land use emissions, and this is one reason why their results differ from other scenarios. However, climate feedbacks are quite uncertain, and including them in estimates of land use emission scenarios may or may not improve these estimates.
- In general, the IS92 scenarios do not cover the range of input assumptions found in published scenarios related to land use.

6.5.5 Population and GNP Assumptions of the IS92 Scenarios¹

It was previously noted that both energy related and land use related emission estimates are strongly influenced by the wide range of assumptions about GNP and population growth. Although a detailed analysis of these assumptions is outside the scope of this report, the following paragraphs highlight some tentative conclusions and important issues concerning economic and population assumptions.

6.5.5.1 GNP Assumptions

As noted earlier, in most cases assumptions about future rates of GNP growth have an even greater influence on emission scenarios than population assumptions. We begin by briefly reviewing the GNP growth assumptions of the IS92 scenarios.

The *medium* assumptions of the IS92 scenarios (IS92a and b) are partly based on the reference scenario of the Energy and Industry Sub-Group of the First IPCC Assessment (ESG, 1990) for the period up to 2025. *Near-term* growth rates in the ESG scenario were adjusted downwards in Eastern Europe, CIS, and Persian Gulf, to reflect the consequences of events occurring at the beginning of the 1990s. As noted by the developers of the IS92 scenarios (Leggett, et al., 1992), the medium assumptions for near-term economic growth are generally below or at the low end of the range given by World Bank for 1990-2000 (Table 6.9). In addition, the medium assumptions for economic growth in the period 1990-2025 are lower than most regions experienced from 1965 to 1989 with the exception of Africa, Eastern Europe and the CIS (Table 6.9). For these regions it was assumed that structural adjustments will lead to higher than historical growth in the *medium-term*. For the period 2050-2100, all of the IS92 scenarios assume that economic growth will slow because of saturation of consumption and expected slower growth of population (Table 6.9).

As to the high and low assumptions of the IS92 scenarios, because of the uncertainty of future trends of economic growth, the low (IS92c) and high (IS92e) estimates span a wide range of possibilities.

The following additional points can be made about the GNP growth assumptions of the IS92 scenarios:

- As noted in Section 6.3, the high and low rates of growth of *global average* GNP in the IS92 scenarios are quite representative of the wide range of views of other published scenarios. However, somewhat higher and lower global growth rates can be found in the literature about energy scenarios.
- With regards to *regional* results, there are many cases in which the IS92 scenarios are higher or lower than any other scenario. In the case of Eastern Europe and the CIS, the IS92 scenarios take into account economic restructuring in these regions, but they assume higher economic growth rates in the near term than more recent scenarios.
- Although the medium assumptions of the IS92 scenarios are lower than historical growth rates, they nevertheless imply a substantial increase in per capita GNP. For example, in the second half of the next century, per capita GNP in East Asia and Latin America will exceed current levels in OECD Europe. Nevertheless, a large gap will remain between incomes of developed and developing regions, and there is the need to develop emission scenarios which

¹Section 6.5.5 has not been reviewed by the full Writing Team of this report.

Table 6.9: GNP growth assumptions (average annual rate)

	World bank†.....								
	Low††		High††	IS92c		IS92a		IS92e	
	1965 1989	1990 2000	1990 2000	1990 2025	1990 2100	1990 2025	1990 2100	1990 2025	1990 2100
OECD	3.2%	2.4%	3.1%	1.8%	0.6%	2.5%	1.7%	3.0%	2.2%
USSR/E.Europe†††	1.3%	3.2%	3.6%	1.5%	0.5%	2.4%	1.6%	3.2%	2.4%
China & CP* Asia	7.6%	5.6%	6.7%	4.2%	2.5%	5.3%	3.9%	6.1%	4.7%
Other	4.7%	3.8%	4.5%	3.0%	2.1%	4.1%	3.3%	4.8%	4.1%
Global	-	-	-	2.0%	1.2%	2.9%	2.3%	3.5%	3.0%

Source of Table: Leggett, *et al.* (1992)

† Source: World Bank (1991).

†† Estimated using projections of regional growth in GDP/capita and country estimates of GDP, population and population growth from 1990 to 2000.

††† World bank data only include several countries in Eastern Europe.

* CP= Centrally planned economies.

1 assume a closing of this income gap.

2

3 *Summing up the discussion of GNP assumptions -- The range of economic growth*

4 *assumptions of the IS92 scenarios is representative of the range of other global scenarios.*

5 *However, they are not always representative on the regional level. Economic growth rates*

6 *of the IS92 scenarios are generally lower than historical rates but they would lead*

7 *nevertheless to large increases in per capita GNP in all regions.*

6.5.5.2 Population Assumptions

11 The influence of population assumptions on future emission estimates is less important than

12 GNP assumptions, but still significant. The following can be said about the *medium*

13 population assumptions of the IS92 scenarios:

- 14 • The medium global assumption of the IS92 scenarios (11.3 billion in year 2100) is based
- 15 on the latest medium estimate of World Bank (1991) (Table 6.10).
- 16 • For year 2025, the IS92 medium population estimate is very close to the latest medium
- 17 estimates of both the UN (1992) and IIASA (1994) (Table 6.10).
- 18 • For year 2100 the three medium estimates are still somewhat close (Table 6.10).

1 • Estimates from World Bank, UN, and IIASA were all made using the cohort-component
2 approach to demographic projections, but they employed very different assumptions about
3 changes in demographic variables. Hence it is significant that the medium estimates are close.

4 With regards to the low and high population assumptions of the IS92 scenarios:

5 • The low and high global assumptions of IS92 (6.4 to 17.6 billion in year 2100) are the latest
6 medium-low and medium-high estimates of the UN (1992) (Table 6.10). (The World Bank
7 did not provide high or low estimates with its most recent medium estimates.)

8 • The low and high estimates of IS92 are the highest and lowest estimates of all published
9 scenarios reviewed in this report. Hence, from the emission scenarios point of view, they
10 cover, and expand, the full range of views about future population.

11 • Recent IIASA high estimates are close to the high estimates of the IS92 scenarios (Table
12 6.10). The low IIASA estimate, however, is somewhat above the IS92 low estimates (Table
13 6.10).

14 Despite the importance of long-term population assumptions in estimating future
15 emissions, there have been few reviews of these assumptions. In one such review, Morita, *et*
16 *al.* (1993) reviewed assumptions of global models and concluded that a not implausible range
17 of global population estimates for year 2100 was between 5.66 to 19.16 billion people. This
18 is somewhat lower and higher than the range of IS92 assumptions (Table 6.10) The lower
19 bound is from Nordhaus and Yohe (1983), while the upper bound is the high estimate from
20 UN (1992), which assumes reproductive rates which actually occurred in Japan during the
21 periods 1947-1950 and 1975-1985. From this perspective Morita, *et al.* judged that the UN
22 high estimate is not impossible. (They made no direct comments about the plausibility of the
23 lower bound).

24 Because population growth assumptions strongly influence future emission estimates,
25 it would be helpful to assess their relative likelihood. This is not possible at this time because
26 of the many unresolved critical issues related to population projections. As one example, the
27 feasibility of *low* estimates is related to the issue of a rapidly aging population. Lutz, *et al.*
28 (1994) pointed out that IIASA's low population estimate for 2100 (the IS92 low estimate is
29 even lower, Table 6.10) is based on assumptions about low fertility and mortality rates, and
30 these low rates would lead to an unprecedented aging of the population. For their low
31 population estimate, the percentage of the population over age 60 increases in industrialized
32 countries from 17.4% to 44.9% between 1990 and 2100, and in developing countries from
33 6.9% to 40.2%. In order to judge the likelihood of the low population estimates of IS92 or any
34 other scenario, it is important to assess the response of society to the increasing burden of an
35 aging population on its social welfare system.
36 (see, e.g. Lutz, *et al.* 1994).

37 Another critical issue is the relationship between high population estimates and the
38 earth's carrying capacity, i.e. the ability of society to provide food and resources for its
39 population. There is very wide disagreement over the size of the earth's carrying capacity;
40 estimates made since the 1980s mostly range from 2 to over 33 billion people, depending on
41 a large variety of assumptions (see review in Heilig, 1994). This range can be compared to
42 the IS92 high population assumption of 17.6 billion people in 2100. If the low figure for
43 carrying capacity is correct then even current population cannot be sustained, whereas the
44 high figure implies that IS92 estimates are theoretically possible from the carrying capacity
45 point of view. In order to judge the feasibility of the high population assumptions of the IS92
46 or any scenario, it would be beneficial to try and narrow the range of estimates about global

Table 6.10 *Population assumptions (in millions)*

Region	World Bank(1991)			UN Med-Low		UN-Med		UN-Med-High		IIASA Low		IIASA Central		IIASA High	
	IS92a, b & e			IS92c & d				IS92f							
	1990	2025	2100	2025	2100	2025	2100	2025	2100	2025	2100	2025	2100	2025	2100
OECD	838	939	903	865	503			1,039	1,359						
USSR & E.-Europe	428	496	513	475	337			540	856						
China & CP Asia [†]	1,218	1,721	1,924	1,526	935			1,881	2,385						
Middle East	128	327	603	272	223			349	693						
Africa	648	1,587	2,962	1,375	1,668			1,807	4,651						
Latin America	440	708	896	682	770			832	1,662						
South & East Asia	1,553	2,636	3,538	2,395	1,979			2,999	5,987						
Total	5,252	8,414	11,312	7,591	6,415	8,472	11,186	9,445	17,592	8,093	9,126	8,955	12,562	9,872	16,090

[†] CP=Centrally planned economics

Source: Leggett, *et al.* (1992), except IIASA estimates from Lutz *et al.* (1994).

1 global carrying capacity.

2 These are only two of the many issues related to demographic studies that require
3 further research and understanding before progress can be made in assessing the likelihood of
4 different population assumptions

5
6 *Summing up the discussion of population assumptions, the plausibility of the medium*
7 *population growth assumption of the IS92 scenarios is supported by other recent population*
8 *estimates. The low and high estimates of the IS92 scenarios cover and expand the range of*
9 *assumptions found in other published scenarios. The IS92 estimates are taken from*
10 *authoritative projections of world population growth, and are not inconsistent with other*
11 *recent population estimates. However, in order to assess the likelihood of the low and high*
12 *population assumptions, more research is needed to improve our understanding of critical*
13 *issues related to population projections such as carrying capacity and population aging.*

14 15 16 6.5.5.3 The Relationship Between GNP and Population

17 In Section 9.1, we proposed "internal consistency" to be one criterium for judging scenarios.
18 One aspect of this is the issue of the consistency between population and GNP assumptions
19 in the IS92 scenarios. This issue was briefly raised by the developers of the scenarios
20 themselves (Leggett, et al., 1994). The IS92 scenarios combine high population with high
21 GNP assumptions, and low population with low GNP assumptions. While this is logical for
22 performing a sensitivity analysis of key input assumptions, it also implies that high population
23 growth can accompany high economic growth, and conversely low population growth with
24 low economic growth. It should be noted, however, that the developers of the scenarios offer
25 the opinion that GNP and population in reality would most likely be negatively correlated
26 (Leggett, et al., 1992).

27 Actually, there are many opinions about the connection between population and GNP.
28 Three of these are:

29 (i) *High population growth is compatible with high economic growth (or low*
30 *population growth with low economic growth).* As noted, this is implied, if not intended, by
31 the IS92 scenarios. In support of this point of view it is argued that a larger population leads
32 to greater intellectual richness in a society, which serves as a springboard for innovation,
33 which can lead to greater per capita wealth.

34 (ii) *Population growth is negatively correlated to economic growth.* The reasoning
35 behind this argument is that improved economic status leads to lower birth rates and
36 eventually lower population growth. This belief is embedded in conventional thinking about
37 the "demographic transition" of societies, which says that fertility in a society goes down as
38 its standard of living goes up. A related point of view is that population growth will lead to
39 resource and capital constraints that in turn, will reduce GNP growth.

40 In support of a negative correlation between population and GNP, Morita, et al. (1994)
41 found a significant relationship between declining total fertility rate and increasing per capita
42 income for Japan as a whole, from 1925 to 1990. Applying this relationship globally, they
43 computed that the fertility rates underlying the IS92a population assumptions should
44 correspond to an effective annual per capita GNP growth rate of 3%. By comparison the
45 IS92a scenarios actually assume a 1.7% annual growth rate. Hence Morita, et al. (1994)
46 suggest that the population and economic assumptions of this scenario may be inconsistent.

(iii) *Population growth and economic growth are independent.* Based on recent extensive field surveys in developing countries, demographers have begun to argue that there is no empirical evidence to support either of the above points of view, and that the fertility rate in many countries is much more clearly related to the educational level of women and the existence of family planning programs than any economic indicators (see, for example, UN, 1987; Westhoff, 1994; and Lutz, 1994).

Summing up the discussion of the relationship between population and GNP growth, there are at least three points of view about this relationship, and it is beyond the scope of this report to pass judgement on their validity. It is important to note, however, that the issue of population and GNP growth is relevant to judging the consistency and likelihood of population and economic assumptions which in turn is needed for improving future emission estimates. Hence, it would be beneficial to improve the understanding of the population-GNP relationship.

6.5.6 What Are the Uses and Limitations of the IS92 Scenarios?

In evaluating the IS92 scenarios it is important to recall that they were developed only to accomplish Purpose 1. The IS92 scenarios clearly fulfill the "mandatory" requirements of this purpose. Specifically, their global results span the range of results of published scenarios, and in this way can be said to reflect the current range of views about future emission estimates. Moreover, the IS92 scenarios are among the most comprehensive scenarios available in their coverage of all important greenhouse gases and precursors of ozone and sulfate aerosol. Also the scenarios are sufficiently documented in reports and in digital form to allow their comparison with other scenarios. As a consequence, they are useful for Purpose 1, namely as input to atmosphere/climate models for examining the environmental/climatic consequences of not acting to reduce greenhouse emissions.

It is noted that the IS92 scenarios do not fulfill all of the "recommended" requirements for Purpose 1 listed in Table 1. In particular, the documentation of land use assumptions having to do with forestation, rice production and animal production may not be adequate enough to allow other researchers to reproduce the IS92 calculations. There are also a number of cases in which the input data of the IS92 scenarios were not representative of the range of views found in other scenarios. As noted above, this applies in particular to input assumptions about specific world regions. As to the other recommended requirements of Purpose 1 -- sensitivity analysis and internal consistency, no judgement was made about the IS92 scenarios.

Although the IS92 scenarios were designed with Purpose 1 in mind, it is still interesting to question whether they are useful for the other purposes of scenarios. With regards to Purpose 2 (evaluating the consequences of intervention to reduce emissions), the IS92 scenarios make assumptions about controlling local air pollution problems and these measures would also have an affect on greenhouse gas emissions. Moreover, the IS92b scenario includes information available in 1992 about the goals of OECD countries for stabilizing or reducing CO₂ emissions. This information, however, must be updated with the latest information on emission targets. In general, it was found that emission estimates of the IS92 scenarios are

substantially higher than policy scenarios published in the literature. Hence, they should not be used as intervention scenarios.

The IS92 scenarios are inadequate for Purpose 3 (estimation of feasibility and costs of policies) primarily because they do not include mitigation measures specifically targeted towards global warming (they were also not intended for this purpose). In addition, they have somewhat limited use as reference scenarios for mitigation studies because their regional results and input assumptions are in many cases outside the range of views found in published scenarios.

The IS92 scenarios are not appropriate for Purpose 4 (input to negotiating possible emission reductions) because of the high uncertainty of current greenhouse gas estimates from many sectors and countries. It is again noted that the scenarios were not intended for this purpose.

6.6 Recommendations

6.6.1 The Question of New Scenarios

At this time, it is recommended that researchers use the IS92 scenarios as input to atmosphere/climate models for examining the consequences of not intervening to reduce greenhouse gas emissions (Purpose 1).

As to the likelihood of individual IS92 scenarios -- the input assumptions of the IS92a scenario are in some cases intermediate as compared to other published scenarios. In addition, the population estimates of IS92a are equal or close to the medium estimates recently published by three different international organizations. However, sensitivity analysis showed that there are no strong reasons for selecting it as the "medium case" scenario. Therefore, at this time, analysts are encouraged to use the full range of IS92 scenarios for Purpose 1, rather than any individual IS92 scenario.

In general, because the IS92 scenarios were not designed and are not suitable for Purposes 2, 3, and 4, new scenarios may be needed to fulfill these purposes. It should be noted that this evaluation did not judge the suitability of other scenarios to satisfy these purposes. New scenarios, if developed, should include improvements in the estimation of non-CO₂ emissions, particularly from the land use sector.

Although we did not judge the adequacy of all currently available scenarios, it is still likely that new reference scenarios will be needed to fill some current gaps in information. For example:

- New *non-intervention* scenarios are needed to take into account recent events that will affect the trend of emissions, such as (i) economic restructuring, especially in the CIS, Eastern Europe and Latin America, and (ii) consequences of the General Agreement on Trade and Tariffs. (We note that restructuring in Eastern Europe and the CIS were partly taken into account in the IS92 scenarios, but it would be worthwhile to include more recent information about this restructuring.)
- New *non-intervention* scenarios are needed that explore a variety of economic development

1 pathways, for example, a closing of the income gap between industrialized and developing
2 regions.

3 • New *intervention* scenarios are needed that take into account the commitments that are part
4 of the newly ratified Climate Convention. As one example, a new reference scenario is needed
5 which contains the emission targets of the Convention.

6.6.2 The Process of Developing Scenarios

7 If new or updated scenarios are developed under the IPCC or other organizations, it is
8 recommended that the following approach be taken to develop these scenarios. The IPCC
9 should provide a "common umbrella" under which different groups can develop comparable,
10 comprehensive emission scenarios. This process should draw on current experience in
11 harmonizing scenarios and model calculations by such groups as IPCC Working Group I (CO₂
12 stabilization exercise), the Energy Modeling Forum and International Energy Workshop
13 (global/regional energy scenarios), and the CHALLENGE network of the International Institute
14 for Applied Systems Analysis (CO₂ emission scenarios). The process should also emphasize
15 the following:

16 -- *Openness*. Scenario development should be open to the wide participation of the research
17 community, particularly from developing countries;

18 -- *Pluralism*. A diversity of groups, approaches and methodologies should be encouraged,
19 although they should be harmonized as noted below;

20 -- *Comparability*. Reporting conventions of input and output should be standardized. This
21 could include: regional aggregation of countries, reporting years, classification of emissions,
22 minimum set of reporting variables, specification of sectors, and units of measure.

23 -- *Harmonization*. Input assumptions and methodologies of the scenarios should be
24 harmonized in order to provide a common benchmark for scenarios from different groups.

6.6.3 Integrated Scenarios

25 To accomplish Purpose 3 of emission scenarios (estimation of feasibility and costs of
26 mitigation measures) it is not only important to analyze the costs of emission reductions, but
27 also to assess the costs and benefits of the impacts of emissions on the natural environment
28 and society. Therefore, the next generation of emission scenarios should be coupled with their
29 impact on environment and society in the form of consistent, comprehensive *integrated*
30 scenarios of global change. These scenarios would cover not only the trend of emissions, but
31 also changes in the atmosphere and ocean, and the impact of these changes on society, the
32 terrestrial environment, and the marine environment. We recommend that the IPCC
33 encourages the development of integrated scenarios.

6.6.4 Dissemination of Scenarios

34 Current and new scenarios should be widely disseminated to countries, international
35 organizations, non-governmental organizations and the scientific community. As part of this
36 effort, a central archive should be established to make available the results of new scenarios
37 to any group. Where feasible, the archive should also make available some aspects of the
38 models and input assumptions used to derive scenarios. In addition, special effort is needed
39 to improve capabilities of researchers to analyse and develop scenarios, especially in
40 developing regions. The IPCC can have a major role in these activities.

Appendix 6.1 Scenarios reviewed in this report (THIS IS IN DRAFT FORM)

Code	Scenario Identification		Type(*)	Reference
1-1	IS92a	IPCC 1992	G R	Leggett et al. (1992)
1-2	IS92b	IPCC 1992	G R	Leggett et al. (1992)
1-3	IS92c	IPCC 1992	G R	Leggett et al. (1992)
1-4	IS92d	IPCC 1992	G R	Leggett et al. (1992)
1-5	IS92e	IPCC 1992	G R	Leggett et al. (1992)
1-6	IS92f	IPCC 1992	G R	Leggett et al. (1992)
1-7	IS92 S1 : IPCC 1992 Sensitivity 1 (High Deforestation, High Biomass)		G R	Leggett et al. (1992)
1-8	IS92 S4 : IPCC 1992 Sensitivity 4 (Halt Deforestation, High Plantation)		G R	Leggett et al. (1992)
2-1	Nordhaus 50th% (50th percentile)		G	Nordhaus et al. (1993)
2-2	Nordhaus 95th% (95th percentile)		G	Nordhaus et al. (1993)
2-3	Nordhaus 5th% (5th percentile)		G	Nordhaus et al. (1993)
3-1	Edmonds 50th% (Scenario B, 50th percentile)		G R	Edmonds et al. (1985)
3-2	Edmonds 95th% (Scenario B, 95th percentile)		G R	Edmonds et al. (1985)
3-3	Edmonds 5th% (Scenario B, 5th percentile)		G R	Edmonds et al. (1985)
4	Rogner		G R	Rogner (1986)
5	Mintzer		G R	Mintzer (1987)
6-1	CH ₄ -Efficiency Methane Economy (Efficiency Scenario)		G	Ausubel et al. (1987)
6-2	CH ₄ -Long -wave Methane Economy (Long-wave Scenario)		G	Ausubel et al. (1987)
7-1	SCW EPA (Slowly Changing World)		G R	Lashof et al. (1990)
7-2	RCW EPA (Rapidly Changing World)		G R	Lashof et al. (1990)
7-3	RCWA EPA(RCW with Accelerated Emissions)		G R	Lashof et al. (1990)
7-4	EPA High Reforestation (Halt Deforestation, High Plantation)		G R	Lashof et al. (1990)
8-1	IPCC SA IPCC 1990		G R	IPCC (1990)
8-2	SA-High IPCC 1990 (Scenario A, High)		G R	IPCC (1990)
8-3	SA-Low IPCC 1990 (Scenario A, Low)		G R	IPCC (1990)
8-4	IPCC-EIS Energy Industry Sub-group 1990 (reference)		G R	Ogawa (1990)
9	Ogawa (Institute of Energy Economics, Japan)		G R	Ogawa (1990)

(*) G = Global, R = Regional (National), P = Policy Scenarios

Code	Scenario Identification		Type(*)	Reference
10	Bach		G	Bach (1991)
11-1	Edmonds-Reilly	(Scenario 1)	G R	Edmonds et al. (1991)
11-2	Edmonds-Reilly	(Scenario 2)	G R	Edmonds et al. (1991)
12-1	GREEN (1991)		G R	Burniaux et al. (1991)
12-2	GREEN (1992)		G R	Burniaux et al. (1992)
12-3	GREEN (1993)		G R	Martins (1993)
13-1	Global 2100	(Scenario 1)	G R	Manne et al. (1991)
13-2	Global 2100	(Scenario 2)	G R	Manne et al. (1991)
13-3	Global 2100	(1992 Scenario)	G R	Manne et al. (1992)
14	TEC		G R	Okada et al. (1991)
15	Anderson (World Bank)		G R	Anderson et al. (1992)
16	CHALLENGE		G R	Schrattenholzer (1992)
17	CRTM		G R	Rutherford (1992)
18	ECS '92 (Dynamics as usual)		G R	Messner et al. (1992)
19-1	IEA 1992	International Energy Agency	G R	Vouyoukas (1992)
19-2	IEA 1993	International Energy Agency	G R	Vouyoukas (1993)
20-1	IEW 1992	International Energy Workshop	G R	Manne et al. (1992)
20-2	IEW-50%	International Energy Workshop Poll (50th percentile)	G R	Manne et al. (1993)
20-3	IEW-84%	International Energy Workshop Poll (84th percentile)	G R	Manne et al. (1993)
20-4	IEW-16%	International Energy Workshop Poll (16th percentile)	G R	Manne et al. (1993)
21	ITF-D4		G R	Shishido (1992)
22	AGE		G R	Manne et al. (1993)
23-1	AIM, High	Asian Pacific Integrated Model (High Scenario)	G R	Matsuoka et al. (1993)
23-2	AIM, Low	Asian Pacific Integrated Model (Low Scenario)	G R	Matsuoka et al. (1993)
23-3	AIM	Asian Pacific Integrated Model (Medium Case)	G R	Matsuoka et al. (1993)
24	CETA		G R	Peck et al. (1993)
25	DICE		G	Nordhaus (1993)
26	FUGI 7.0		G R	Onishi (1993)
27-1	IMAGE 2.0	1993	G R	Alcamo et al. (1993)

(*) G = Global, R = Regional (National), P = Policy Scenarios

Appendix 6.1 (continued)

Code	Scenario Identification	Type(*)	Reference
27-2	IMAGE 2.0 CW (Conventional Wisdom Scenario)	G R	Alcamo et al. (1994)
27-3	IMAGE 2.0 No Biofuels (No Biofuels Scenario)	G R	Alcamo et al. (1994)
28-1	Manne-Richels-50th%-(50th percentile)	G R	Manne et al. (1993)
28-2	Manne-Richels-95th%-(95th percentile)	G R	Manne et al. (1993)
28-3	Manne-Richels-5th%-(5th percentile)	G R	Manne et al. (1993)
28-4	Global 2100, 1994	G R	Manne et al. (1994)
29	MERGE	G R	Manne et al. (1993)
30	12RT	G R	Manne (1993)
31	WEC, World Energy Council (Scenario B)	G R	WEC (1993)
32	ESCAPE	G R	Rotmans et al. (1994)
33-1	ESCAPE S1 (Business as Usual)	R	ESCAPE (1991)
33-2	ESCAPE S3 (Emission Control)	R P	ESCAPE (1991)
34-1	Bashmakov-Base (Russia)	R	Bashmakov (1992)
34-2	Bashmakov-Efficiency	R P	Bashmakov (1992)
35-1	Sinyak BAU (Business as Usual Scenario)	R	Sinyak et al. (1992)
35-2	Sinyak Efficiency (Energy Efficiency Scenario)	R P	Sinyak et al. (1992)
36-1	EMF-12 Lowest	R	Weyant (1993)
36-2	EMF-12 Highest	R	Weyant (1993)
36-3	EMF-12 20% Lowest	R P	Weyant (1993)
36-4	EMF-12 20% Highest	R P	Weyant (1993)
37	He (Gradual Changing Scenario)	R	He et al. (1993)
38-1	UNEP-base (Baseline Scenario)	R	Christensen et al. (1994)
38-2	UNEP-abate (Abatement Scenario)	R P	Christensen et al. (1994)
39-1	Houghton-Population*	G	Houghton (1991)
39-2	Houghton-Exponential Extrapolation*	G	Houghton (1991)
39-3	Houghton-Reforestation*	G	Houghton (1991)

(*) G = Global, R = Regional (National), P = Policy Scenarios

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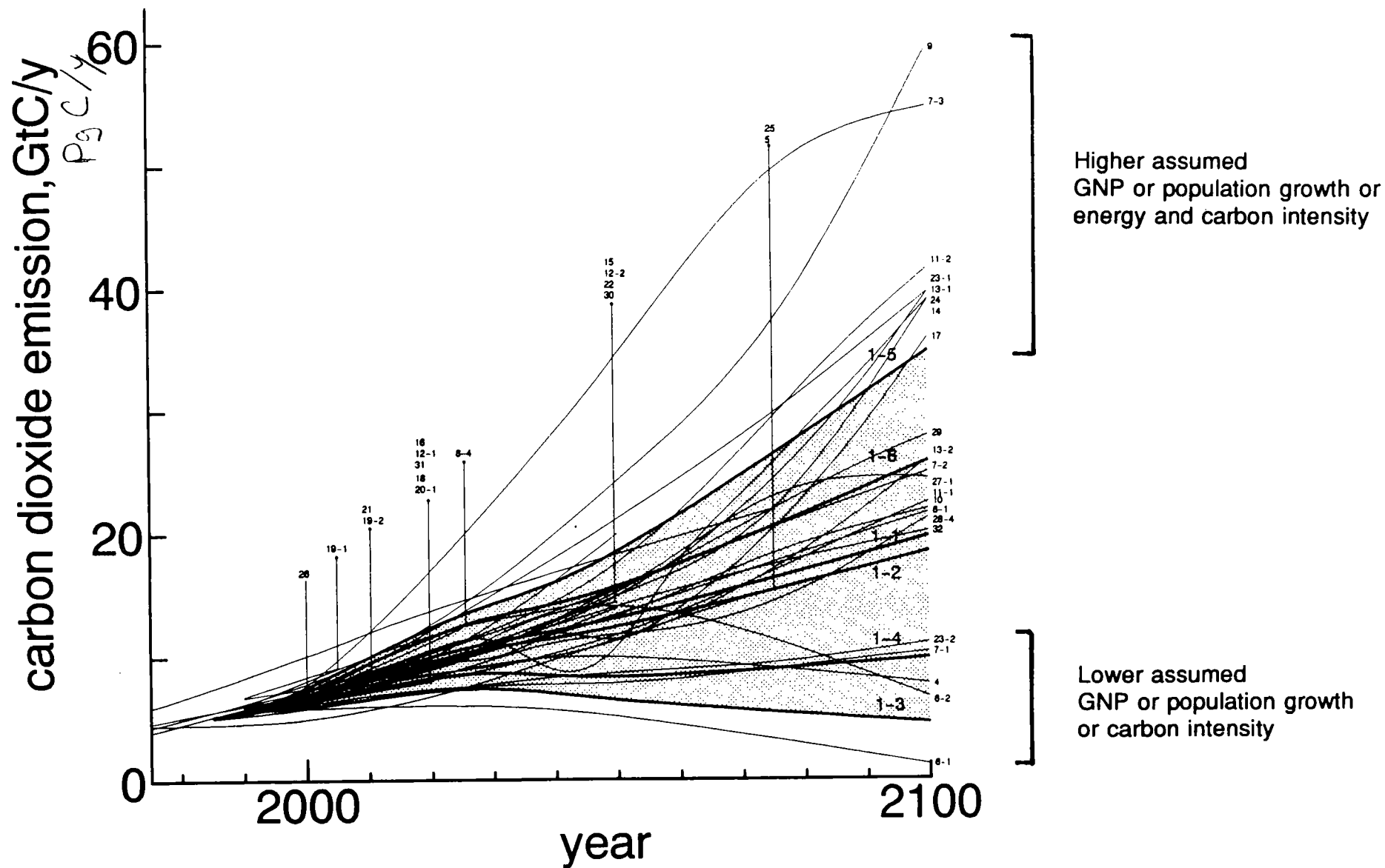


Figure 6.1: Trends of energy-related global CO₂ emissions of various scenarios. Shaded area indicates coverage of IS92 scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

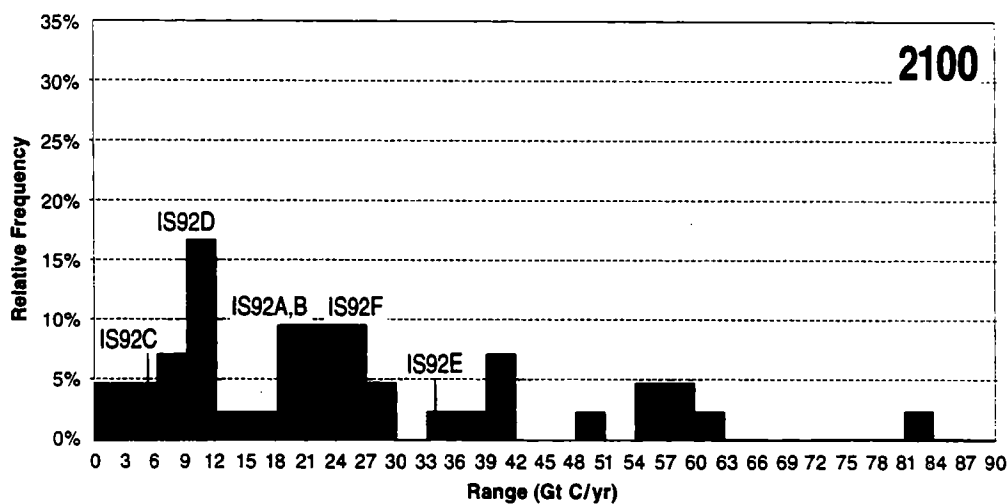
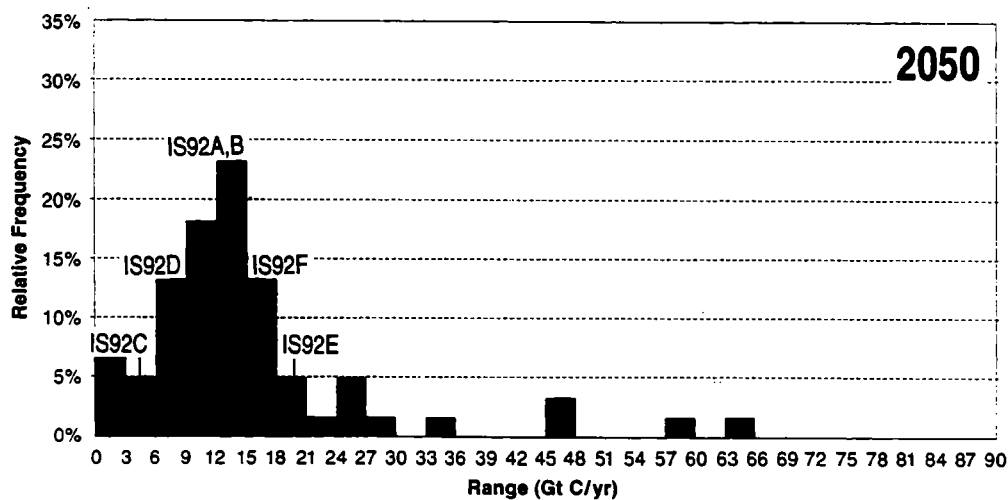
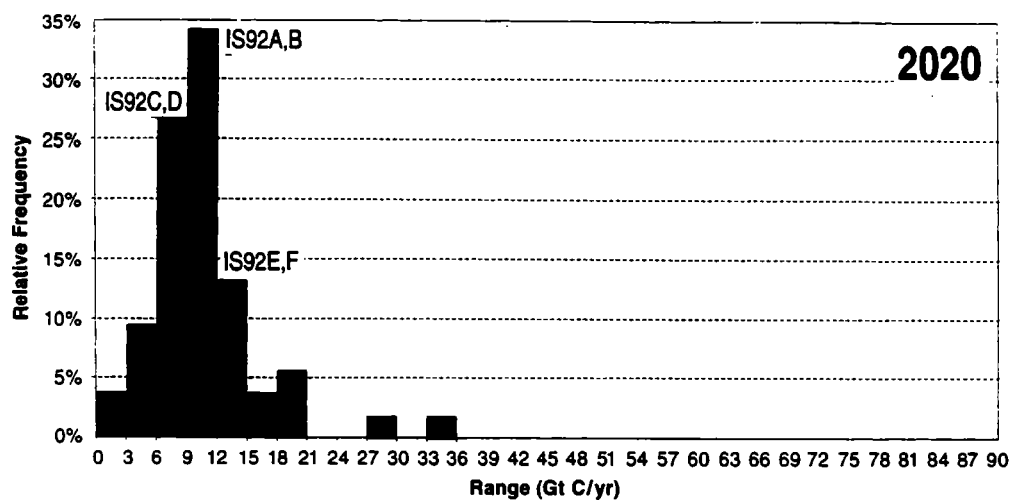


Figure 6.2: Histograms depicting distribution of different scenario estimates of energy-related global CO₂ emissions for three scenario years.

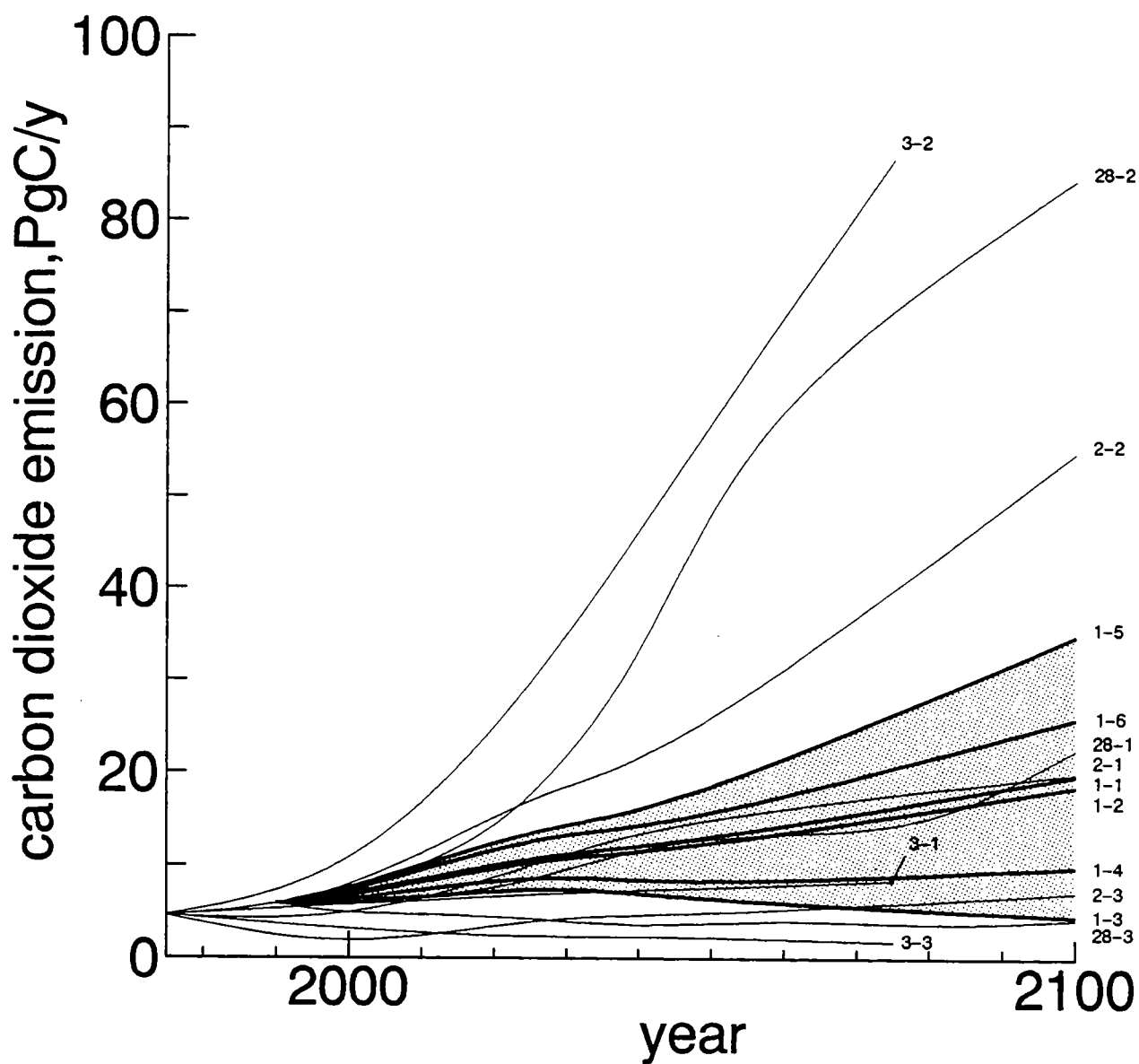


Figure 6.3: Results from uncertainty analyses showing 5th and 9th percentile of global CO₂ emissions. Also shown are IS92 estimates (code numbers beginning with "1"), with their range indicated by the shaded area (IS92 results are not from uncertainty analysis). Numbers correspond to list of scenarios in Appendix 6.1.

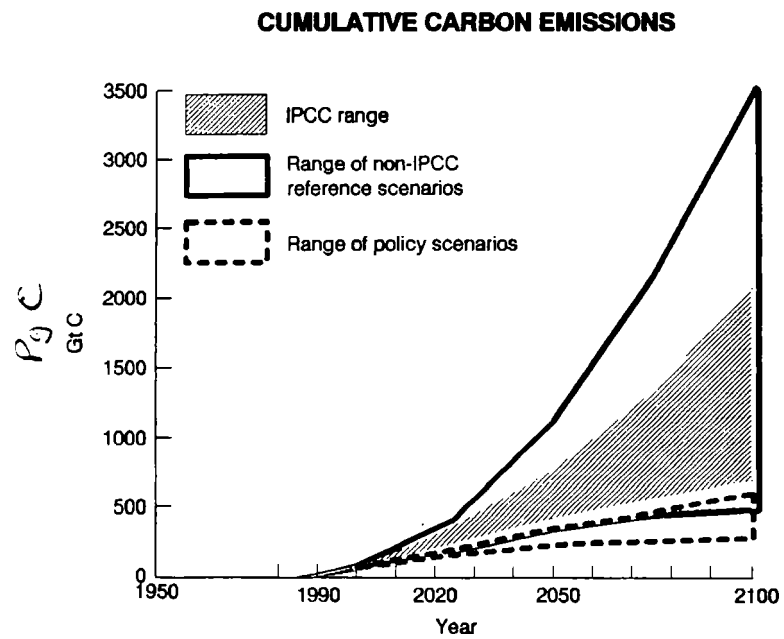


Figure 6.4: Range of cumulative energy-related global CO₂ emissions from IS92 and other published scenarios.

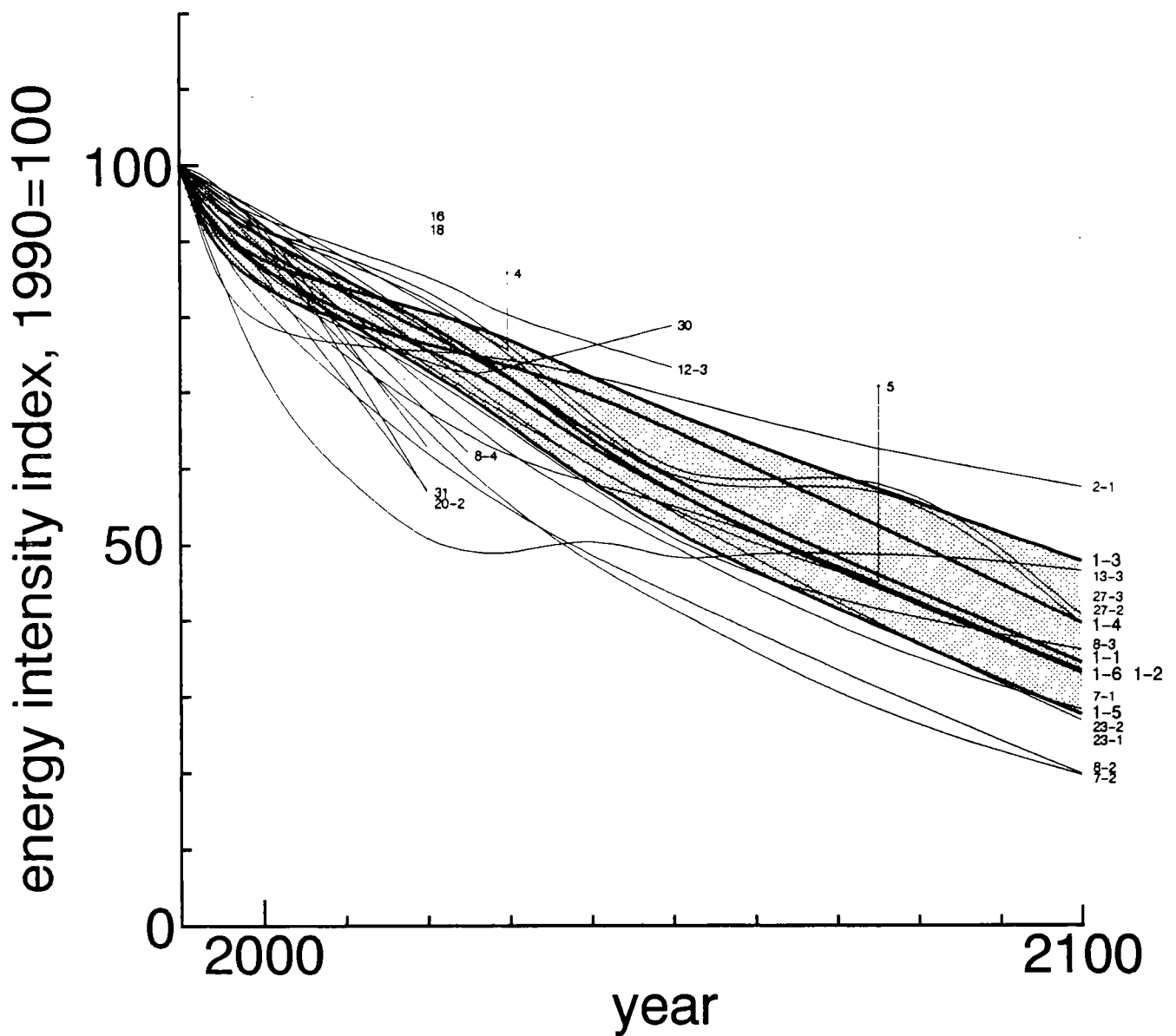


Figure 6.5: Trends of energy intensity for various global scenarios. Shaded area indicates range of IS92 scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

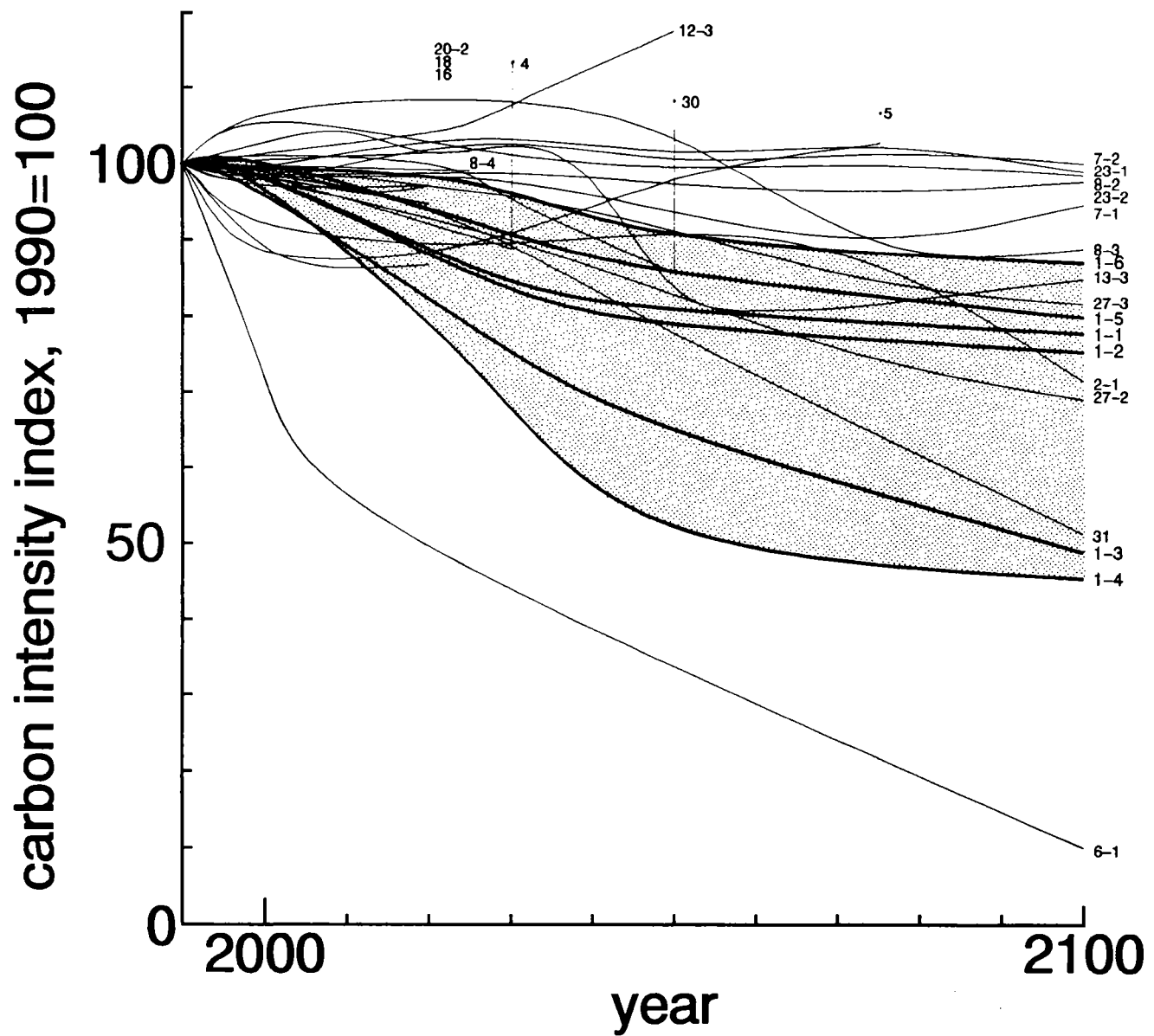


Figure 6.6: Trends of carbon intensity for various global scenarios. Shaded area indicates range of IS92 scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

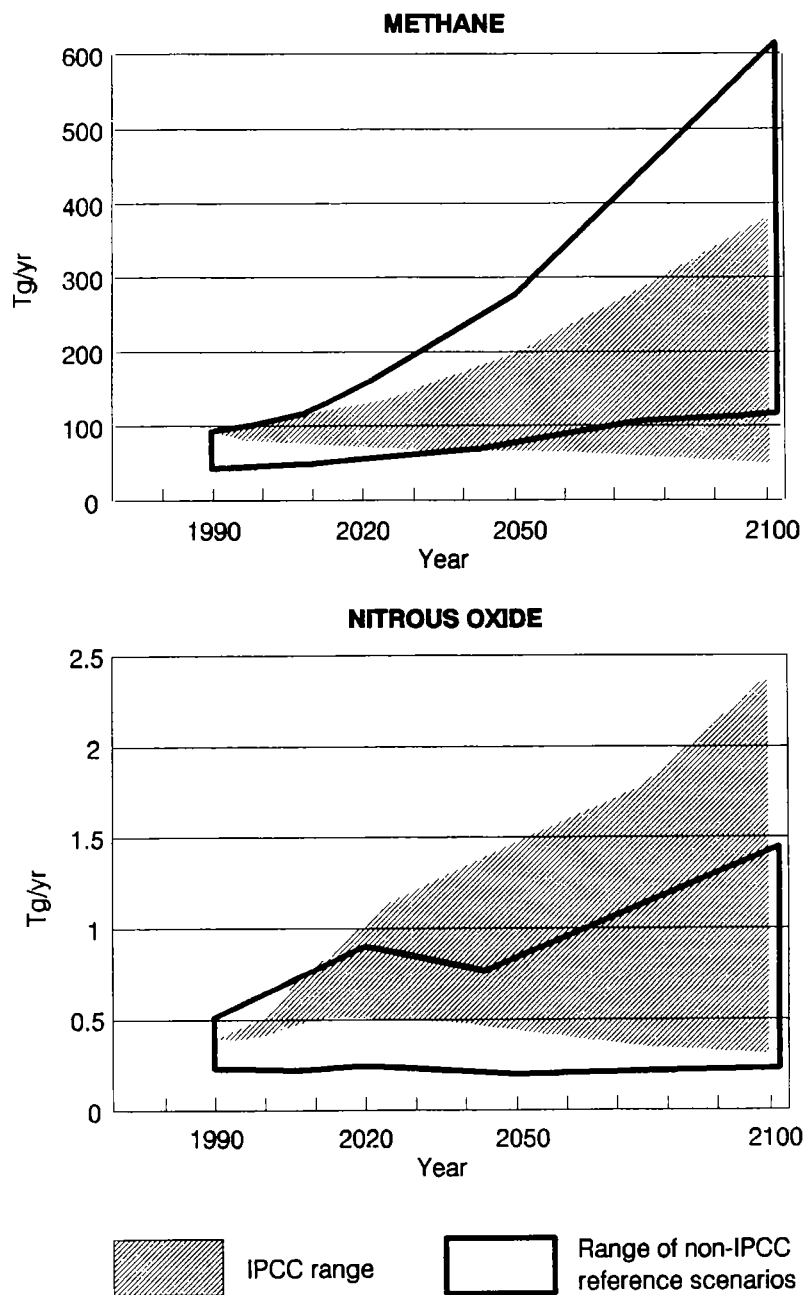


Figure 6.7: Range of CH_4 and NO_x energy-related global emissions from IS92 and other published scenarios.

REGIONAL CARBON EMISSION SCENARIOS

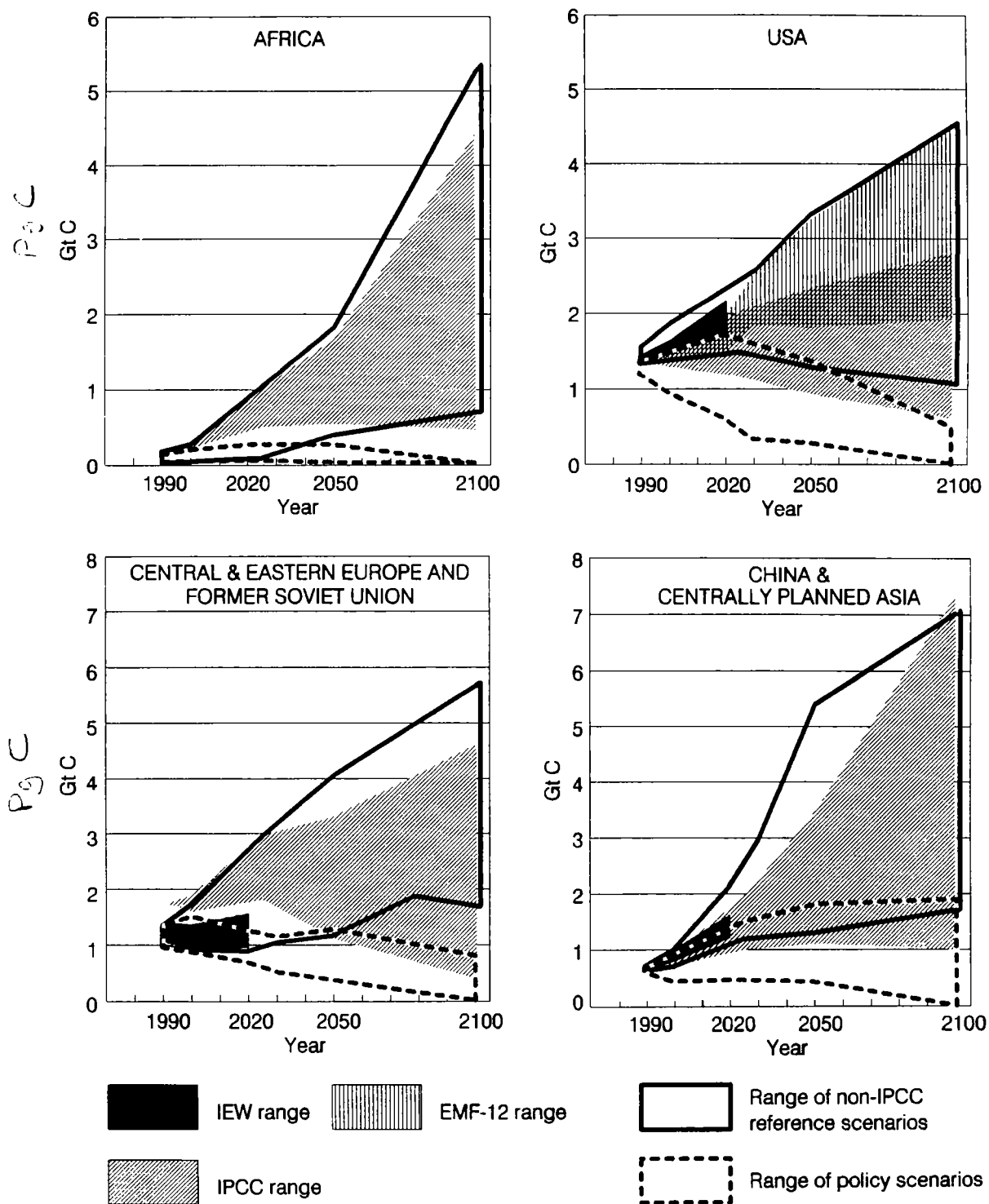


Figure 6.8: Range of regional CO₂ emissions from IS92 and other published scenarios.

REGIONAL ENERGY INTENSITY SCENARIOS

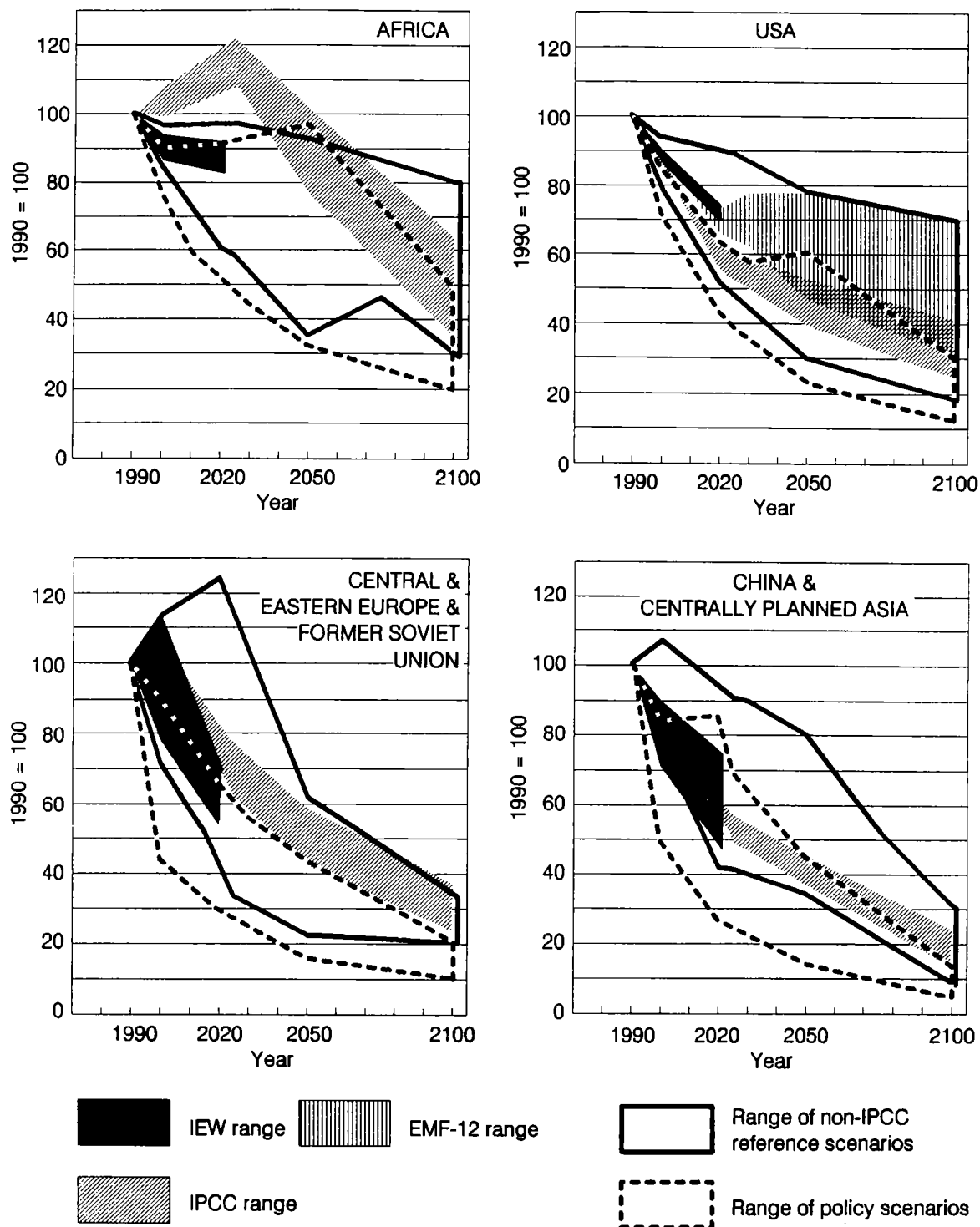


Figure 6.9: Range of regional energy intensities from IS92 and other published scenarios.

REGIONAL CARBON INTENSITY SCENARIOS

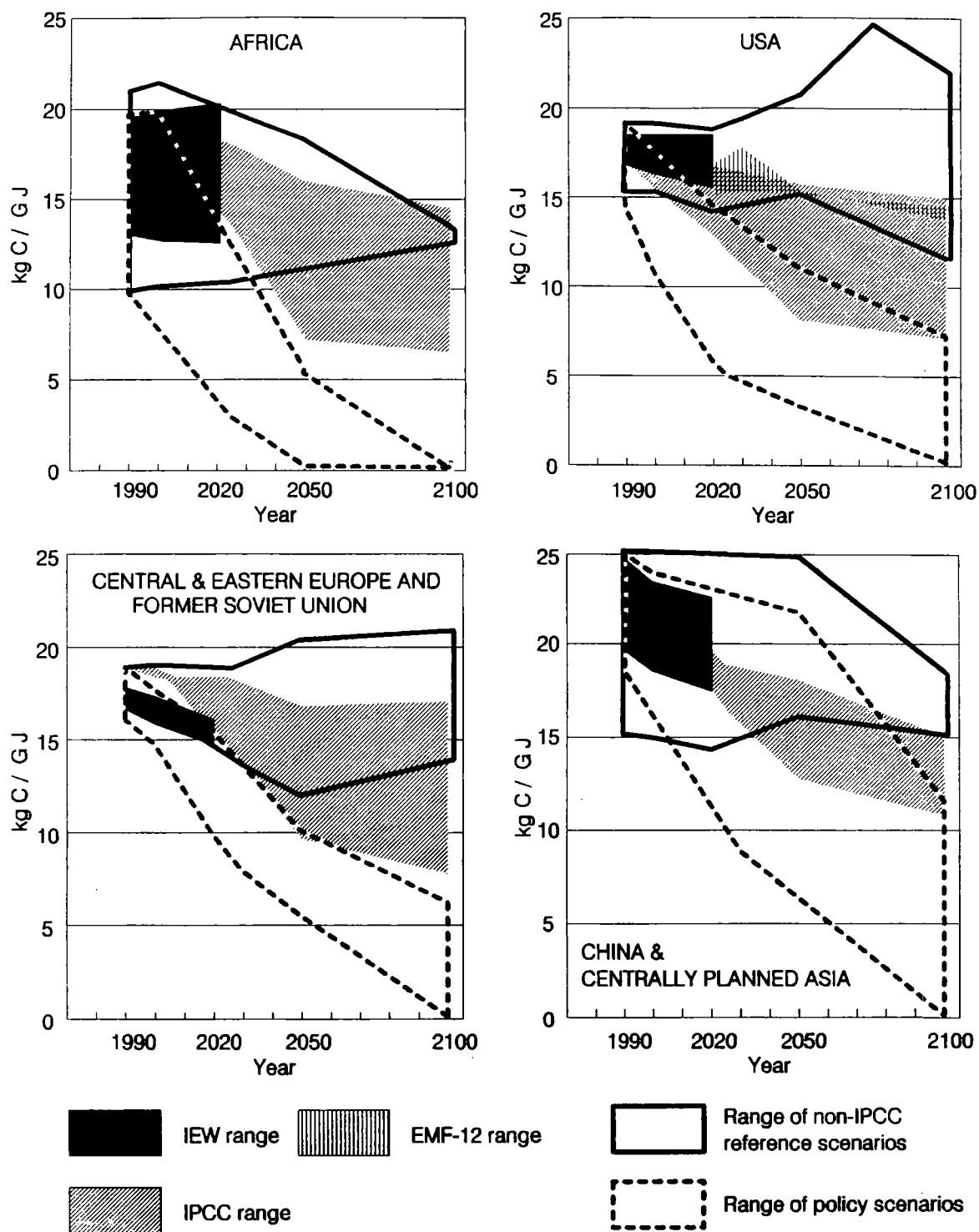


Figure 6.10: Range of regional carbon intensities from IS92 and other published scenarios.

UNCERTAINTY ANALYSIS OF ENERGY-RELATED CARBON EMISSIONS COMPARED TO IS92a

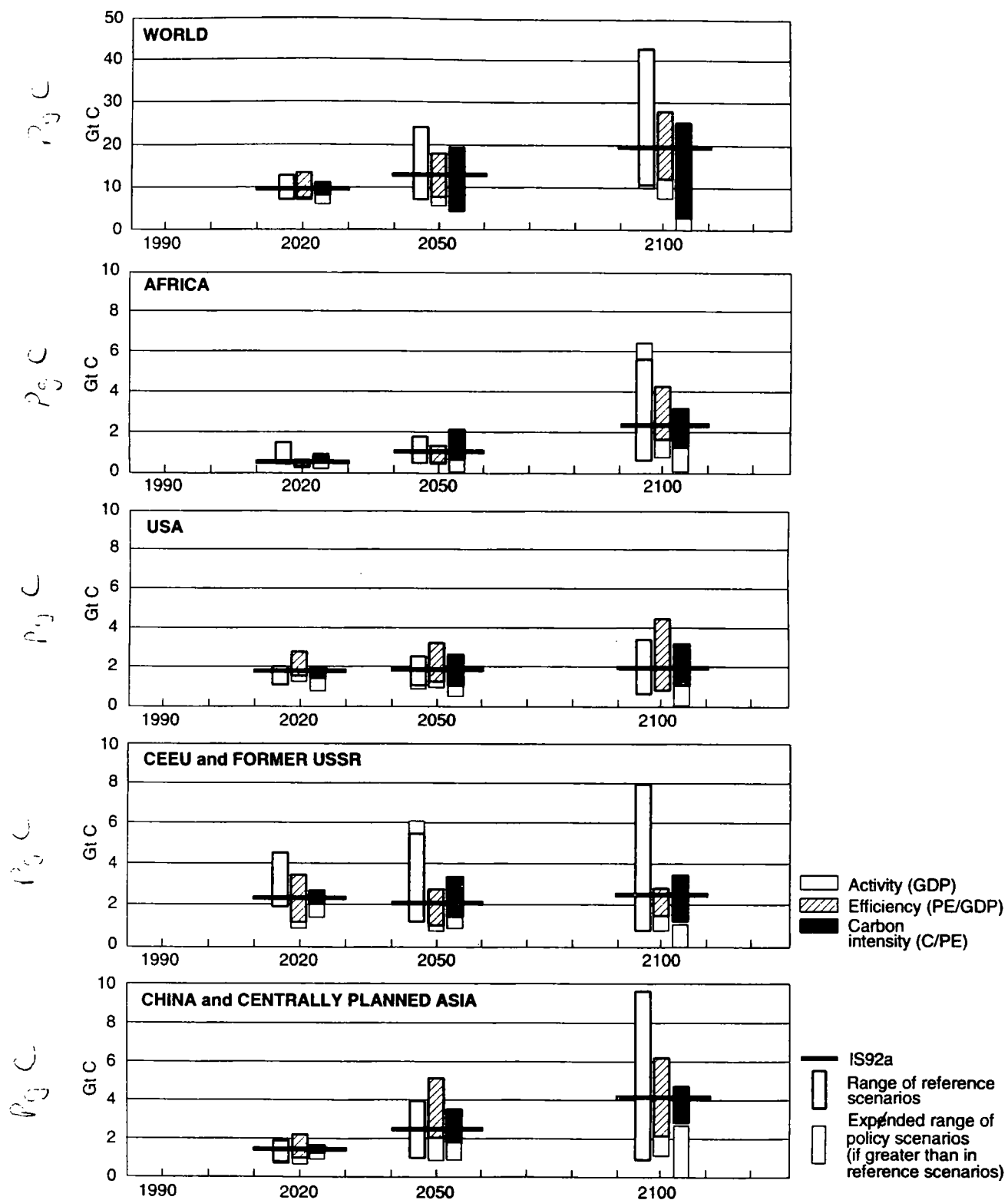


Figure 6.11: Uncertainty analysis of energy-related CO₂ emission estimates relative to the IS92a scenario.

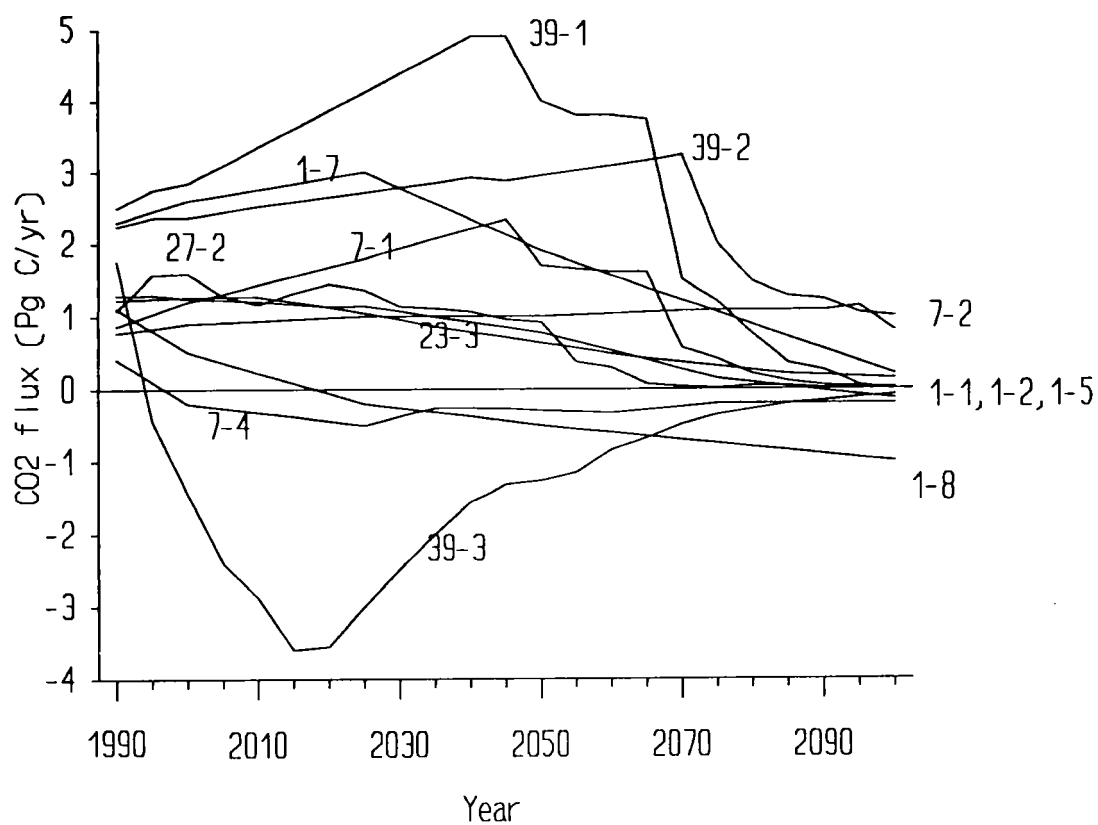


Figure 6.12: Comparison of global scenarios of CO₂ fluxes from deforestation. Numbers correspond to list of scenarios in Appendix 6.1.

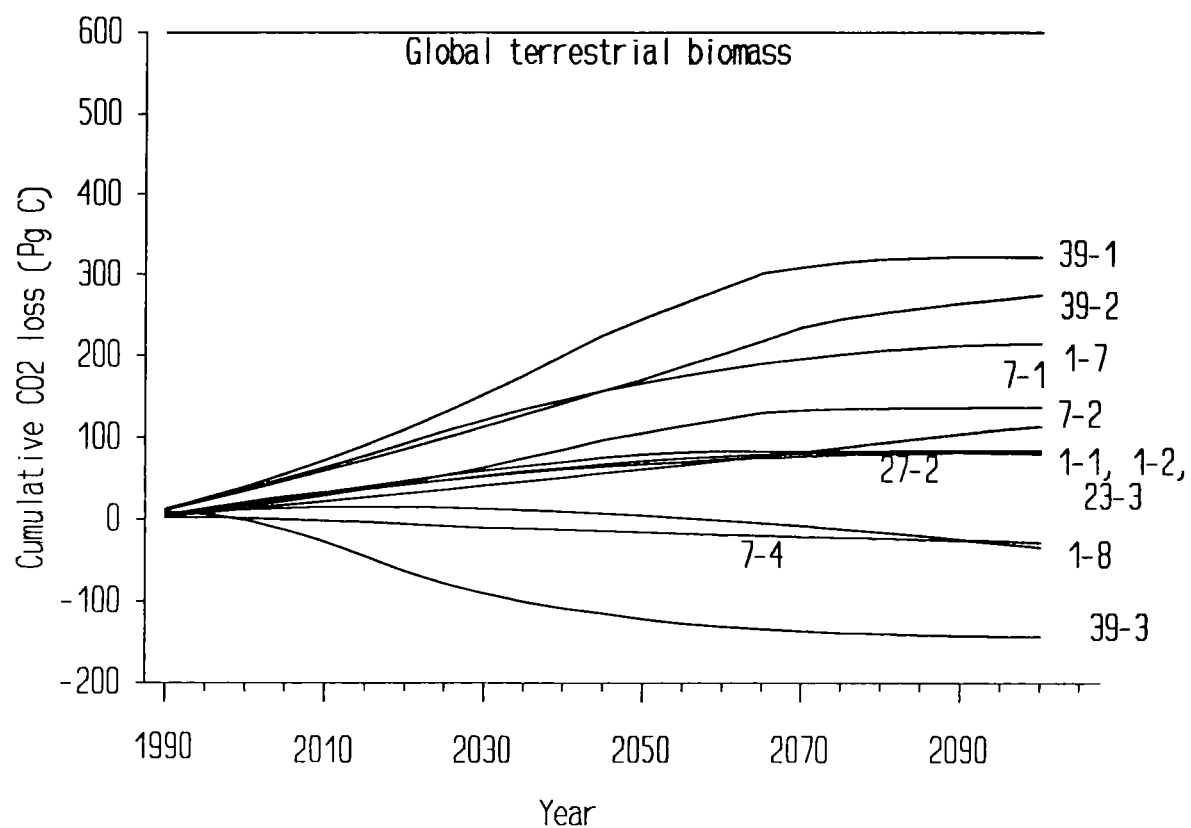


Figure 6.13: Comparison of cumulative global CO₂ fluxes from deforestation for different scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

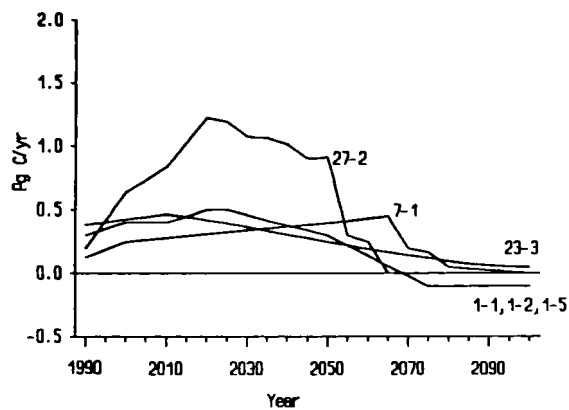


Figure 6.14a: CO₂ fluxes from deforestation for Africa for different scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

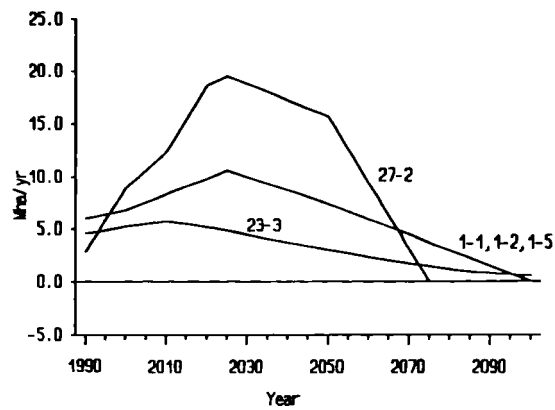


Figure 6.14b: Deforestation rates for Africa for different scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

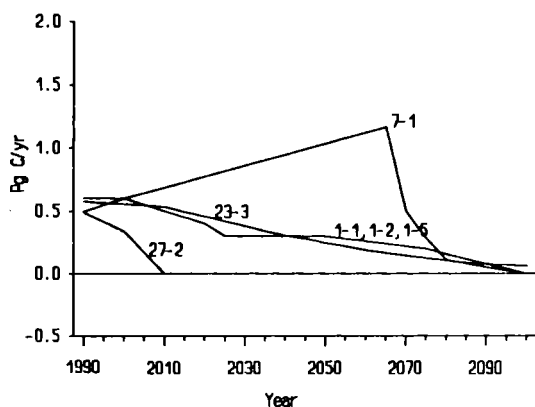


Figure 6.15a: CO₂ fluxes from deforestation for Latin America for different scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

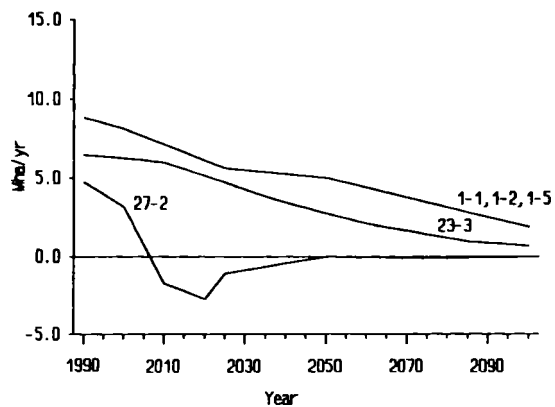


Figure 6.15b: Deforestation rates for Latin America for different scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

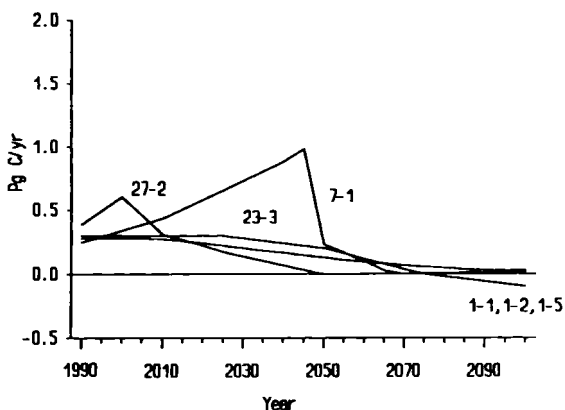


Figure 6.16a: CO₂ fluxes from deforestation for Asia for different scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

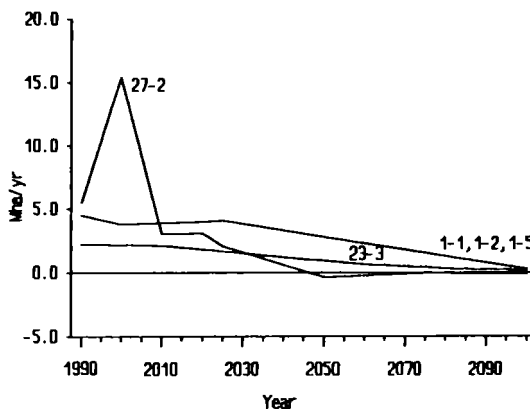


Figure 6.16b: Deforestation rates for Asia for different scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

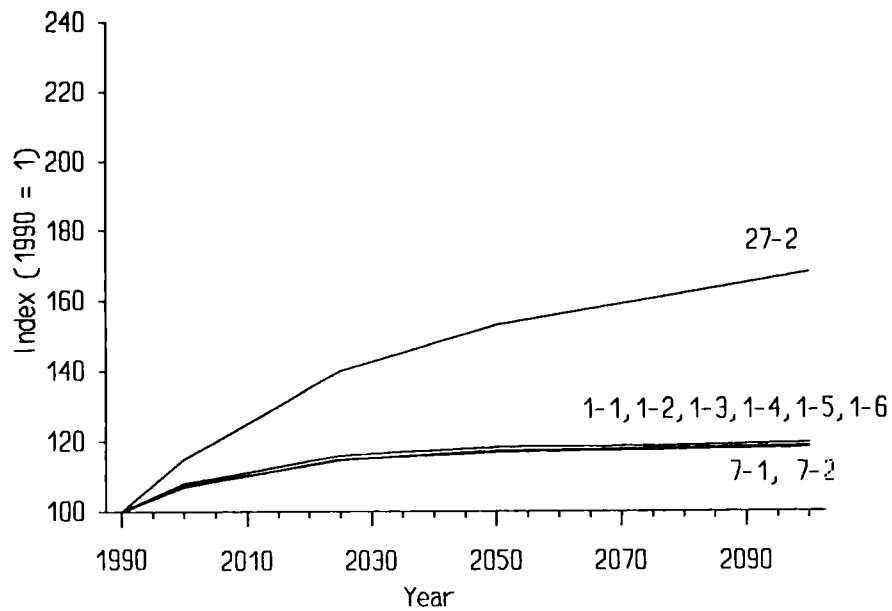


Figure 6.17a: Comparison of development of rice yields for China and Centrally Planned Asian countries for different scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

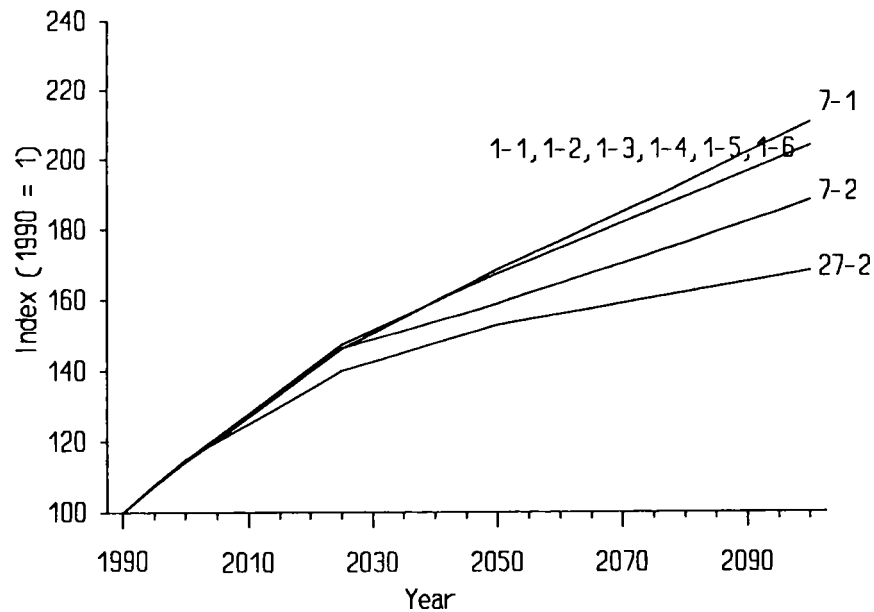


Figure 6.17b: Comparison of development of rice yields for South and Southeast Asia for different scenarios. Numbers correspond to list of scenarios in Appendix 6.1.

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FINANCE

BANKING, HOUSING AND URBAN AFFAIRS
JOINT ECONOMIC COMMITTEE

October 18, 1993

How do we connect?
Environment-IPCC

Dr. Joseph E. Stiglitz
Council of Economic Advisors
Old Executive Office Building, Room 345
Washington, DC 20500

Dear Dr. Stiglitz:

I am writing to recommend Dr. John Byrne, Director of the Center for Energy and Environmental Policy at the University of Delaware, as coordinating lead author for Working Group III of the International Panel on Climate Change. I have known Dr. Byrne for over eight years during which I have grown to depend upon his advice in energy and environmental policy matters.

Dr. Byrne's economic and policy expertise is well established not only in the U.S. but abroad. He has been advisor to the governments of Britain, China, Finland, India and Korea in energy and environmental matters. He has outstanding knowledge of the areas of energy efficiency, renewable energy development, external valuation and equity considerations in greenhouse policy analysis. I understand that Dr. Byrne has also worked extensively with researchers at the Chinese Academy of Science, the Tata Energy Research Institute (India) and the Korea Energy Economics Institute. I believe as a coordinating lead author Dr. Byrne would make valuable contributions to Working Group III's institutional capacity building needs and in assessing existing research on the effectiveness of different policy instruments in the context of the Climate Change Convention.

I support Dr. Byrne's selection for coordinating lead author and recommend him highly and without reservation. If you have any questions concerning this recommendation, please do not hesitate to call me.

Sincerely,

Bill Roth

William V. Roth, Jr.
U.S. Senate

WVR/pck

cc: Mr. Rafe Pomerance

He's an outstanding scholar.

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Environment-IPCC 001

FAX COVER SHEET

DATE November 1, 1993

TO: Dr. Erik F. Haites

Head, Technical Support Unit

Working Group III, IPCC

145 King Street West, Suite 1002, Toronto, Ontario, M5H 3X6 Canada

Telefax (416) 369-0922

FROM: Prof. Akihiro Amano

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Telefax 078-881-8100

NUMBER OF PAGES: 16(excluding cover page)

MESSAGE:

I am sending my draft of the material for the Writing Team 1 to Professor Goldemberg.

Sincerely yours,

Akihiro Amano

Prof. Akihiro Amano

Post-It™ brand fax transmittal memo 7871		# of pages > 17
To <i>Dr. Joseph Shalitz</i>	From <i>Erik Haites</i>	
Co.	Co.	
Dept.	Phone # <i>(416) 369-0900</i>	
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October 31, 1993

Akihiro Amano

VII Measuring Climate Influences and Change

Indicators Required for Monitoring Climate Influences

In order to monitor progress in meeting global environmental objectives, indicators of the discrepancy between actual developments and targets are required. Furthermore, in order to set targets, we need to measure the true social costs and benefits of limiting greenhouse gas emissions. Therefore, indicators required for monitoring climate influences need to cover

- measures of emissions,
- measures of damages (or benefits of abatement), and
- measures of abatement costs.

Uncertainty About Trace Gas Emissions

Future damages attributable to current greenhouse gas emissions are highly uncertain. This reflects uncertainty about at least

- (a) how changes in today's emissions of various greenhouse gases would affect future atmospheric stocks (or abundances) of these gases and thus future radiative forcing;
- (b) how changes in the time-path of radiative forcing would affect future climates; and
- (c) how changes in future climates would affect some appropriate measure of human welfare.

Global Warming Potential

In relation to question (a) mentioned above, IPCC developed the concept of "global warming potential (GWP)" to evaluate relative contributions of various greenhouse gases to global warming. Different gases have different remaining time in the atmosphere with different warming potential. Therefore, their relative contributions depend on the time horizons used. The following table shows the relative contributions of typical GHGs when the time horizon is 100 years.

Table 1 GWP and Relative Contributions to Global Warming

Trace Gas	Estimated Lifetime (years)	GWP	1990 Emissions (tera grams/year)	Relative Contribution over 100 Years (%)
CO ₂	*	1	26,000	61
Methane	10	21	300	15
N ₂ O	150	290	6	4
CFC ₁₁	60	3,500	0.3	2
CFC ₁₂	130	7,300	0.4	7
Other				11

*Approximate lifetime is 120 years.

Source: IPCC (1990)

The sources of greenhouse gases are many. It follows that projecting GHG emissions requires detailed modelling of the sources and their expected rates of change over time. Accurately forecasting GHG emissions depends especially on forecasts of energy use over time, including forecasts of the composition of the various energy sources.

Although GWP is a useful concept in formulating comprehensive approaches to greenhouse gas abatement policies, Eckaus (1992) and Schmalensee (1993) criticize the concept of GWP on the ground that the GWP implicitly sets the economic opportunity costs of an increment in radiative forcing equal. These opportunity costs will vary over time, and hence the reduction of the emissions of the various greenhouse gases at different times and places will impose different economic costs.

A measurement, therefore, is required of the foregone economic opportunities imposed by emissions reduction. According to these authors, optimal policies for greenhouse gas emissions control require comparisons of the discounted marginal damages of emissions from different gases, but the global warming potential (GWP) index, which is most often used to compare greenhouse gases, is not based on such a damage comparison. This is another place where damage analysis involves difficult problems of economic valuation.

Deficiencies in the National Accounts

In measuring the climate influences and in setting policy targets for the global warming issue, the current system of national accounts and particularly GNP have been considered as unsatisfactory indicators and information systems.

1. Defects in reflecting current welfare

GNP has long been looked upon as an indicator of how well a nation is doing or of national well-being. However, the assessment in the conventional national accounts is restricted to the monetized sectors of the economy. Not all activities and factors leading to human welfare are included. (Dimensional Bias)

2. Inadequacies of measuring environment and natural resources

Because of the inadequate ability of GNP to reflect the environment and the "quality of life", and of the weaknesses in the ability of the national accounts to reflect the possible deterioration of a nation's resource base, the economic activity measured in these indicators may not represent a sustainable path over the long run. The aggregation via net value added in market prices may deviate from the activities' real social contributions due to the discrepancies between social and private costs. (Externalities Bias)

3. A poor measure of social and economic performance

The conventional national accounts data respond poorly to changes in

environmental and resource conditions. Pollution, congestion of parks and wilderness areas and the depletion of natural resources are unfortunate side effects of economic growth. On the other hand, increased expenditures on medical services or for household cleaning due to increased pollution levels are treated as positive outputs. (Output Anomaly)

4. Inconsistent treatment of income and wealth

The inconsistency arises because the conventional national accounts measure the depreciation of certain forms of capital, such as plant and machinery, but neglect to account for the depreciation of other forms of capital such as natural resources and environmental capital, as represented by the nation's stock of clean air, water, soil, wilderness areas, non-renewable resources, etc. Accumulation and decumulation of other forms of capital such as human capital are also neglected. (Imputation Bias)

5. Neglect of important determinants of economic activity

The services of natural resources and the environment influence production and consumption activities in much the same way as the services of human capital, plant, and equipment. Neglecting environmental and natural resources distorts the picture of production in two ways. (1) It overlooks the production of some undesirable outputs (e.g., pollution) and (2) it leaves out a number of crucial inputs to both desirable and undesirable product. Thus, it may hamper the ability to develop an integrated policy approach. (Depreciation Asymmetry)

Approaches to Modify GNP and National Accounts

The World Bank Survey by Peskin and Lutz (1990) classified the existing approaches into four groups:

- (1) environmental expenditures approach that identifies pollution abatement and other environmental expenditures but leave the conventional GNP unchanged (United States);
- (2) physical accounting approach to account for flows and stocks of resources using physical units of measurement (Norway and France);
- (3) depreciation approach that adjusts GNP and NNP by subtracting out the value of natural resource depletion (Repetto); and
- (4) comprehensive resource and environmental accounting approach in both physical and value terms (the Netherlands-Hueting, UN Statistical Office, and Peskin).

In terms of the complexity and coverage, (1) is most narrowly focused and (4) is most complex. The differences in complexity and coverage also reflects different policy objectives. Thus, (1) has been aimed at supporting the analysis of the macro-economic effects of environmental policy; (2) is well suited to support the management of natural and environmental resources; (3)

addresses sustainability issues in developing countries that are heavily relying on exploitation of natural resources to promote development; and (4) appears to be designed for detailed analyses of environmental-economic interactions in highly developed countries that may hinder the sustainability of long-term growth process.

One way of looking at these approaches is to see how GNP and national accounts are modified. The simplest approach leaves the national accounts as they are and provides counterbalancing information through isolating 'defensive' expenditures. The next step would be to construct an alternative national income measure by correcting for defensive expenditure. Additional corrections of other environmental damages would be possible, through estimates of peoples' willingness to pay for preventing environmental capital losses. Finally, further corrections of other environmental degradation could be made by estimating the cost of measures required to attain certain standards with respect to environmental quality and resource stocks.

Extent of Defensive Expenditures

Leipert and Simonis (1988) estimated that the share of defensive expenditures represented by costs of compensatory economic activity in FRG has been in the order of 1.5% of GNP and rising. Reference is made to other studies that incorporate wider range of estimates, reporting a figure of some 6% of GNP. In the Japanese 'Net National Welfare (NNW)' measure (Economic Council of Japan (1973)), pollution and waste control costs consistent with quality standards are deducted from GNP, among other corrections. NNW modifies GNP on the basis of recalculated values of private and public consumption, services rendered by capital and durable consumer goods, leisure time, extra-market activities, environmental pollution, and urbanization. Pollution control cost corrections were calculated to be in the order of 2-10% of GNP. Uno (1988) and Uno and Shishido (1988) report some more recent results. Pollution control costs rose sharply from 1955 to 1970 (from 0.2% to 9.4% of GNP), but with the tightening of environmental standards these costs dropped steadily to the 1985 level of 2.2% of GNP.

The Overall Costs of Environmental Policies

The United States Environmental Protection Agency (1990) reported that increasingly tighter regulations have driven the annual direct costs of air, water and land pollution abatement and control from 1.5 per cent of GNP in 1979 to 1.9 per cent in 1989. It expects that over the next decade, the direct costs will continue to rise, amounting to 2.8 per cent of GNP by the year 2000.

Jorgenson and Wilcoxon (1990) applied their disaggregated general equilibrium model and found that the 1985 level of GNP was reduced by 2.6 per cent as a result of environmental policy. Hazilla and Kopp (1990) estimated by a

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different general equilibrium model that the total social cost of compliance was 1.75 per cent of GNP in 1985 and 3.75 per cent in 1990. Applied dynamic general equilibrium models can take into account the general equilibrium interdependence and intertemporal repercussions so that these estimates of social costs include elements which are absent in the direct cost estimates.

Basic Functions of Indicators

The conventional system of national accounts and GNP data attempt to serve two general functions: provision of measures of economic performance and of information data system for policy analysis and economic modeling. The same is true for the different approaches to environmental accounting, and various approaches put different emphasis on each of these basic functions. For example, Repetto's approach has a clear aim of correcting the tendency of conventional indicators to overstate development performance. However, for broader questions of analysing various links between economic development and environmental issues, a set of indicators, economic and physical, and for stocks as well as for flows, would be required. (Ahmad *et al.* (1989), Peskin with Lutz (1990), and Lons (1992).)

Satellite System for Integrated Environmental and Economic Accounting, SEEA

United Nations decided to introduce "Satellite System for Integrated Environmental and Economic Accounting (SEEA)" at the new revision of the System of National Accounts. This satellite system will serve as an information system to help formulate policies for sustainable development by integrating physical and monetary data, both for flows and for stocks, in such a manner as to maintain consistency with the existing SNA.

Basic characteristics of the SEEA may be summarized as follows:

- (1) Environment-protection activities in the SNA are disaggregated in greater detail.
- (2) The monetary data in (1) are linked with environment-related information in physical terms.
- (3) Economic uses of the environment are recorded as imputed environmental costs. In addition to market valuation, additional non-market valuation methods such as maintenance valuation and contingent valuation will be applied.
- (4) The concept of production boundaries is extended to include household production and environmental services (disposal services, productive services of land, and consumptive services of the environment).
- (5) An aggregative indicator "Environmentally Adjusted Net Domestic Product (EDP)" is derived by deducting net use (i.e., use minus accumulation) of non-produced natural assets from Net Domestic Product.

The realization of the SEEA can take several versions depending on the objectives and the data availability. Provisional draft of SEEA Handbook

suggests different priorities for developed and developing countries (Table 2).

Table 2 Priorities for Realizing the SEEA

Environmental issues	Physical accounting		Monetary accounting	
	developed country	developing country	developed country	developing country
1. Use of natural assets (exc. discharge of residuals)				
Depletion of				
1.1 Biological assets	+	++	+	++
1.2 Subsoil assets	+	++	+	++
1.3 Water	0	++	0	++
Degradation of land (landscape)				
1.5 Restructuring (urbanization, more roads, etc.)	++	0	+	0
1.6 Agricultural use (soil erosion)	0	++	0	+
1.7 Recreational use	+	++	+	+
2. Product flow analysis	++	0	0	0
3. Degradation of the nat. env. by discharge of residuals				
3.1 Wastes	++	0	+	0
3.2 Waste-water	++	0	+	0
3.3 Air pollution	++	0	+	0
4. Actual environment costs			++	0
4.1 Env. protection activit.			+	0
4.2 Damage costs				

++: high priority, +: medium priority, 0: low priority

Source: Statistical Office of the United Nations (1992).

Human Development Index: An Existing Supplementary Indicator

As an alternative index that is more related to human welfare, the UNDP developed a new human development index (HDI) in Human Development Report 1990 and updated it in the 1992 volume. The HDI gives a composite measure of human development by combining three key components: longevity (measured by life expectancy at birth), educational attainment (measured by adult literacy and mean years of schooling) and income (real GDP per capita adjusted to reflect real purchasing power).

The HDI does not measure absolute levels of human development. It ranks countries in relation to each other, according to how far they have come from the lowest levels of achievement and how far they will have to travel towards the present highest level of achievement on each of the three indicators (see Table 3).

Although the HDI index is not directly related to global environmental issues, the impacts of global warming and its abatement policies upon HDIs of different countries should be assessed. The effects may be mainly through changes in the income component, but side effects of emission abatements may raise HDI through favorable effects on human health.

Table 3 HDI ranking

Industrial Countries			Developing Countries		
	HDI rank	HDI value		HDI rank	HDI value
Canada	1	.982	Barbados	20	.927
Japan	2	.981	Hong Kong	24	.913
Norway	3	.978	Cyprus	25	.912
Switzerland	4	.977	Uruguay	29	.880
Sweden	5	.976	Trinidad & Tobago	30	.876
USA	6	.976	Bahamas	31	.875
Australia	7	.971	Korea, Rep. of	34	.871
France	8	.969	Chile	36	.863
Netherlands	9	.968	Singapore	40	.848
United Kingdom	10	.962	Brunei Darussalam	41	.848
Czechoslovakia	27	.897	Somalia	151	.088
Hungary	28	.893	Guinea-Bissau	152	.088
Poland	32	.874	Djibouti	153	.084
USSR	33	.873	Gambia	154	.083
Bulgaria	35	.865	Mali	155	.081
Yugoslavia	37	.857	Niger	156	.078
Malta	38	.854	Burkina Faso	157	.074
Portugal	39	.850	Afghanistan	158	.065
Albania	49	.791	Sierra Leone	159	.062
Romania	60	.733	Guinea	160	.052

UNDP (1992).

Measuring Benefits of Global Warming Mitigation

It is surprising that relatively little attention has so far been devoted to the global warming issue as such in the discussions of environmental accounting. As a consequence, researches on measuring benefits of mitigating global warming have been proceeding rather independently, looking for appropriate methods of accounting damages to be caused by global warming. (Nordhaus (1990a, 1990b, 1992a, 1992b, 1993), Cline (1992a, 1992b, 1993a, 1993b), Pankhauser (1992), and Pankhauser and Pearce (1993).)

It is sometimes useful to follow Peck and Teisberg (1992) in distinguishing two categories of possible damages from global warming: (a) damages represented in the national income accounts and (b) those not reported in these accounts (Table 4).

Tables 5-7 summarize currently available estimates of damages from global warming at the benchmark of doubling carbondioxide equivalent concentration in the atmosphere. Only William Cline looks at the impacts of very long-term warming beyond the $2\times\text{CO}_2$ benchmark. Also, only Samuel Pankhauser has attempted regional estimation.

For the standard case of doubling carbondioxide equivalent concentration in the atmosphere with the equilibrium increase of mean surface temperature (the climate sensitivity parameter) at 2.5 degree Celsius, available estimates are rather close with each other, ranging from 1.1 to 1.4 per cent of GNP. For higher mean surface temperature rise, the damage estimates show a tendency of

Table 4 Damages from Global Warming

Damages included in national income accounts	Sea Level Rise
Climate dependent activities	Land Loss
Agriculture	Shore Protection
Forestry, Fisheries, Other	Damages excluded from national income accounts
Construction	Unmanaged Natural Systems
Water Transportation	Wetlands
Air Conditioning Costs	Forests
Reduced Space Heating Costs	Biological Diversity
Water and Sanitary	Amenities of Everyday Life
Hotels, Lodging, Recreation	

Source: Peck and Teisberg (1992).

non-linear relationship with more than proportionate increase in damages. Two caveats. First, most studies extend the estimates obtained in the United States to the world as a whole. Fankhauser (1992) and Fankhauser and Pearce (1993) warn us that non-OECD countries may subject to larger damages. Excluding the special case of the former Soviet Union, the non-OECD damage mounts to about 2.8 per cent of GNP, twice the OECD average. The main causes for this high estimate are health impacts and the high portion of wetlands found in developing countries.

Second, damages not included in the conventional national accounts are rather hard to evaluate, and damage estimates of various authors vary substantially in this respect. Moreover, there seems to be a tendency that the higher the proportion of non-conventional items in total damage, the larger the damage as a percentage of GNP.

Pollution Abatement Spillover

Glemsrød et al. (1992) explicitly incorporated the evaluation of side-benefits arising from measures to abate CO₂ emissions. Stabilization of CO₂ emissions is assumed from the year 2000. Side-benefits of this stabilization scheme are estimated as around 19 billions of 1986 NOK in 2010, making up for about two-thirds of the GDP loss. Important sources of side-benefits are emissions of NOx, road damage, traffic congestion, traffic accidents, and noise.

Table 3 Comparison of Damage Estimates (1) (billion dollars and % of GDP)

	2XCO ₂			Very long-term warming
	Cline (2.5°C)	Fankhauser (2.5°C)	Titus (4°C)	Cline (10°C)
Agriculture	17.5	7.4	1.2	95.0
Forest loss *	3.3	-1.8	43.6	7.0
Species loss *	4.0	6.4	-	16.0
Sea level rise	7.0	10.7	5.7	35.0
Electricity	11.2	6.8*	5.6	64.1
Nonelectric heating	-1.3	-	-	-4.0
Human amenity *		-*	-	
Human life *	5.8	16.6	9.4	33.0
Human morbidity *		-	-	
Migration	0.5	0.5	-	2.8
Hurricanes	0.8	0.2	-	6.4
Construction		-	-	
Leisure activities	1.7	-	-	4.0
Water supply availability	7.0	13.7	11.4	56.0
pollution	-	-	32.6	-
Urban infrastruc.	0.1	-	-	0.6
Air pollution troposphere ozone *	3.5	6.4	27.2	19.8
other		-	-	
Mobile air cond.	-	-	2.5	-
Total (A)	61.1	66.9	139.2	335.7
Percent of GDP	1.1	1.4	2.5	6.1
Items with * Total (B)	16.6	27.6	80.2	75.8
(B) as % of (A)	27.2	41.3	57.6	22.6

Base year: Cline, Titus: 1990; Fankhauser, 1988. Titus: median estimate.

* Fankhauser places air conditioning under human amenity.

Source: Cline (1993).

* Items not represented in national income accounts.

Table 6 Comparison of Damages (2) (billions of 1988 dollars and % of GNP)

	Fankhauser	Cline (1992) ^a	Nordhaus (1991 ^{a,b})
Coastal defense	0.2	1.0	7.5
Dryland loss	2.1	1.5	3.2 ^b
Wetland loss *	5.6	3.6	"
Species loss *	6.4	3.5	"
Agriculture	7.4	15.2	1.0
Forestry	-1.8	2.9	small
Fishery	-	-	small
Energy	-	9.0	1.0
Water	13.7	6.1	"
Other sectors	-	1.5 ^d	"
Amenity *	6.8	-	"
Life/morbidity *	16.6	>5.0	"
Air pollution	6.4	>3.0	"
Migration	0.5	0.4	"
Natural hazards	0.2	0.7	"
Total (bn\$) (A)	64.1	53.5	48.6
(% of GNP, 1988)	(1.3)	(1.1)	(1.0)
Items with * Total (B)	35.4	12.1	
(B) as % of (A)	55.2	22.6	

^a Transformed to 1988 values based on % GNP estimates. ^b Total land loss (dry- and wet-lands). ^c Tourism. ^d Not assessed categories, estimated at 3.4% of GNP. * Items not represented in national income accounts.

Source: Fankhauser and Pearce (1993).

Table 7 Damage by Region at 2XCO₂ (Billion dollars and % of GNP)

	EC	USA	USSR	CHINA	N-OECD	OECD	WORLD
Coastal def.	0.1	0.2	0.0	0.0	0.9	0.5	.4
Dryland loss	0.3	2.1	1.2	0.0	5.9	8.1	14.0
Wetland loss *	4.9	5.6	1.2	0.6	15.7	15.9	31.6
Species loss *	7.1	6.4	2.6	1.5	10.9	17.3	28.2
Agriculture	9.7	7.4	6.2	7.8	16.0	23.1	39.1
Forestry	-4.1	-1.8	-2.9	1.1	-0.8	-10.0	-10.8
Fishery ^c	-	-	-	-	-	-	-
Energy	-	-	-	-	-	-	-
Water	14.1	13.7	3.0	1.6	11.9	34.8	46.7
O. sectors	?	?	?	?	?	?	?
Amenity *	7.0	6.8	-0.7	0.7	3.0	20.1	26.1
Life/morbid ^b *	22.0	16.6	3.9	7.3	32.0	57.3	89.3
Air pollution	3.5	6.4	2.1	0.2	2.3	2.0	4.3
Migration	1.0	0.5	0.2	0.6	2.1	1.1	3.2
Nat. hazards ^c	0.0	0.2	0.0	0.2	2.1	1.1	3.2
Total (bn\$) (A)	65.6	64.1	16.8	21.6	103.1	182.1	285.2
(% GNP)	(1.5)	(1.3)	(0.7)	(6.1)	(1.8)	(1.4)	(1.5)
Items * Total (B)	41.0	35.4	7.0	11.8	61.6	110.6	172.2
(B) as % of (A)	62.5	55.2	41.7	54.6	59.7	60.7	60.4

^a Fishery loss is included in wetland loss. ^b Mortality only. ^c Hurricane damage only. * Items not represented in national income accounts.

Note: Negative numbers denote benefits ("negative damage").

Source: Fankhauser (1992).

Social Costs of Carbondioxide Emissions

One of the important questions remaining unresolved in the discussion of how to cope with the global warming issue is the extent of desirable, or socially optimal, strategy to reduce greenhouse gases. On the one hand, the scientific group associated with the Intergovernmental Panel on Climate Change (IPCC) confirmed their earlier recommendation that in order to stabilize climatic change it would be necessary to reduce the level of current emission of CO₂ by 60 per cent (IPCC (1992)). On the other hand, William Nordhaus has been maintaining in a series of his papers that the climatic stabilization or even the emission stabilization is far from optimal from the socio-economic view point, and that the socially optimal abatement path is much closer to the uncontrolled path (Nordhaus (1990a, 1990b, 1992a, 1992b)). According to his view, percentage rates of reduction of greenhouse gases along the optimal path will be as low as 10 per cent in around 2000 and 14 per cent in around 2100. The levels of carbon taxes will also be moderate along the optimal path, ranging from about 6 dollars per ton carbon in 2000 to a little above 20 dollars per ton carbon in 2100.

Cline (1992b), on the other hand, considers that a more aggressive policy of stabilizing current CO₂ emissions at an annual rate of 4 GtC would be justified if (a) future benefits are given higher weights by means of lower social rate of time discount, and if (b) the risk averse stances of policy makers are taken into account. Although Cline's conclusions are not derived from an optimization model, they are based upon a detailed global cost/benefit analysis. Carbon taxes required for the aggressive policy are \$50/tC in 2013, \$100/tC in 2020, \$200/tC in 2025, and remain at \$250/tC in 2054 and after. These rates are much higher than those of Nordhaus but are more or less comparable to those obtained in other global models of carbondioxide emissions for the case of emission stabilization (see, e.g., Dean and Hoeller (1992)). Pankhauser and Pearce (1993) report estimates of social costs (or the shadow price) of CO₂ emissions derived from optimization models. Table 8 shows their summary with an addition of Cline's estimates which were obtained by running Nordhaus' DICE model with the social rate of time discount equivalent to 5 per cent per annum. Cline's exercise demonstrates the importance of the discount rate in evaluating socially optimal paths of greenhouse gas emissions.

Table 8 The Social Costs of CO₂ Emissions (\$/tC)

	1991-2000	2001-2010	2011-2020	2021-2030
Nordhaus (1991)			7.3	
Ayres and Walter			30-35	
Nordhaus (1992)	5.3	6.8	8.6	10.0
Peck and Teisberg	10-12	12-14	14-18	18-22
CERGE-Fankhauser	20.4	22.9	25.4	27.8
Cline (1993)	45.0 ^a			84.0 ^b

^a 1990. ^b 2025.

Sources: Pankhauser and Pearce (1993) and Cline (1993).

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The level of social costs of greenhouse gas emissions depends not only on the social rate of time discount but also on numerous other factors such as the climate sensitivity parameter, the extent and non-linearity of climate-caused damages, valuation of non-market environmental losses, availability and timing of back-stop technologies, the rates of energy-efficiency improvements, rates of population growth, and so on. The choice between stabilization approaches and optimization approaches hinges crucially upon these factors.

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