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8/14

Francine: —

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these under misc.

Thanks Lisa

—

PROPOSED SCHEDULE FOR THE COMPLETION  
OF THE  
CONTRIBUTION OF IPCC WG III  
TO THE  
IPCC SECOND ASSESSMENT REPORT

1994

End of September

Draft chapters ready for mailing out for peer review (Minimum 6 weeks for the review)

21 November

Deadline for receipt for peer reviews

✓ 28-30 November      Ottawa

Meeting of CLAs/LAs for revising the drafts

1995

2 January

Revised drafts ready for mailing out for governments' review (Minimum 6 weeks for the review)

End February

Deadline for receipt of governments' reviews

✓ 13-15 March      Geneva

Meeting of CLAs/LAs for revision of the drafts

Mid-April

Final drafts ready for mailing out to governments who will approve line-by-line the Summary for Policymakers (SPM) at the third session of WG III and accept the underlying report (Minimum 4 weeks for SPM and 3 weeks for the report)

✓ 26-28 June      Geneva

Third session of WG III. The approved SPM and the report will be forwarded to the IPCC for acceptance at the IPCC eleventh session (4 weeks for review)

✓ 26-29 September      Geneva

Eleventh session of the IPCC

*Secretariat  
[Signature]*



**Massachusetts Institute of Technology  
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To: Sally Kane and Joe Stiglitz, CEA

From: Dick Schmalensee

Date: August 30, 1994

Re: 8/15 Draft Chapter

This was actually enjoyable to read! It needs some work, as the comments that follow indicate, but it will clearly be a very important and widely-read document. First a few more or less general reactions.

1. I think this chapter should contain early on a very basic paragraph or two on externalities and market failure, just as the scientists gave us "the greenhouse effect for toddlers." The fact is, most people simply do not think about environmental issues, and certainly not this one, as economists do. (Indeed, there are even subtle differences between io/regulation and public finance approaches here.) Page 54 is too late to get to this stuff, though it might make sense to keep that level of detail out of the front end.

I also think you need to have something early on about command and control versus other approaches -- CAFE v. gasoline taxes is my favorite... Since the whole world uses command and control, and since engineers turn right to it, I think you need to put down this marker early. (A carbon tax is simply assumed optimal in passing on page 13: this will blow by most readers. The point that you can't assume that efficient policies will be adopted is crucial; don't lose it by obscuring it in this fashion.)

2. I might also add a brief discussion of the nature of the negotiation problem. A naive application of the Coase Theorem (which should surely be mentioned!) would suggest that negotiation among nations, which can write checks to each other, should lead to a Pareto efficient outcome here, even without any sort of world regulator. I think this fails both because contracts involving future "payments" aren't credible/enforceable (thus there are no real property rights) and because nations aren't rational individuals -- there are limits on their abilities to accept changes that make them better off in aggregate.
3. I think there is way too much space devoted to specific costs of warming and estimates of costs of mitigation for a chapter concerned with framework and principles. We need to know that both are uncertain, potentially huge, and likely uneven in their incidence and

that both involve irreversibilities. (A free idea: to my knowledge, nobody has even attempted to prove that the present climate is the best of all possible climates for humans in any sort of long-run steady-state sense. All the cost estimates of which I am aware amount to costs of adapting to change. Given that we are looking at warming *trajectories*, comparative statics, which dominates most impact analysis, really makes little sense. Some of the language in this chapter seems implicitly to assume comparative statics.) We also need to know that time is measured in decades in this problem, with little impact forecast by anybody until several decades into the next century.

4. There is a good deal of duplication, in that the same point is often discussed (at different levels of detail) in several places. Perhaps this is intentional, given the natures of the art form and audience, but it is a bit off-putting and I think increases length needlessly.
5. The policy discussion needs to be tightened in a couple of respects. First, you need to distinguish more clearly between policy choices at the national and international levels. Page 33, for instance, leaps from a discussion of using the income tax system to deal with equity (presumably within nations) to a discussion of "a pollution permit scheme" that seems to operate between nations. This is a huge leap, particularly since "pollution permits" have not yet been defined. (See my first point above.) One can imagine, for instance, a national-level system based on tradable quotas, with command and control used by national governments to meet their objectives. (Early State Department memos on the Framework Convention envisioned a set of command and control Protocols.) Or, one could adopt a tax approach internationally, and seek to coordinate effective carbon taxes, somehow defined. (This would avoid the problem of a country failing to keep its promises because its economy grew too rapidly...)

Second, your discussion of the Framework Convention treats it as the last step in the policy process, not the first step. Clearly the obligations assumed won't stabilize emissions, let alone (the Convention's ultimate objective) atmospheric concentrations, but it is surely a valid criticism (which you must have chosen not to make) that those goals have absolutely no analytical basis. Just as clearly, there will be international negotiations on this issue for decades (unless the scientists really surprise us), and there will be plenty of time to deal with the developing world, should there ever develop the necessary political will there or in the OECD. In the meantime, reviewing national action plans and experimenting with joint implementation will make it easier to adopt stringent plans that are efficient, should we choose to do so. I think it is useful to talk about the Framework Convention and the associated process as defining a "policy architecture" (in the software sense) rather than a particular policy -- since it is not clear to me (see p. 40) that it would have served any useful purpose to have tried to set a long-term world emissions trajectory.

6. I think you badly need a glossary for non-economists. Hire a good editor who does not do economics work to go through and flag all the technical terms, then write definitions

for idiots. (Do chemists know what a rate of return is? No, they don't. They have given *us* glossaries.)

I also have a few more detailed comments.

1. Page 9: Table 1 should show percentages of global emissions over time, so the reader doesn't have to try to calculate it.
2. Page 11: Thanks for the cite, but my point is rather different. The IPCC's GWP measure may be convenient, but it is utterly without any economic rationale. The logical starting point is discounted marginal damages, as I discuss. Even if all greenhouse gases have the same decay rate, CO<sub>2</sub> fertilization would complicate comparisons, as John Reilly (who deserves a cite here) has indicated. After this discussion, I think CO<sub>2</sub> is the only gas mentioned, except for one mention of methane on page 70. (Do a search on "nitrous oxide"...). There are good arguments for an exclusive policy focus on CO<sub>2</sub> in the near term; perhaps you should make them implicitly -- or discuss other gases a bit.
3. Page 18: I think these electricity studies are silly in a world in which people in the U.S. have been migrating for decades to warmer areas where air conditioning is required -- as Schelling and others have noted. Changes in the geographic distribution of population (a reversal of this trend, say), can easily swamp any estimated change in electricity demand. In addition, this has nothing to do with utility. People seem to like to live in cool houses located in warm climates, even though this does involve more consumption of electricity: energy is an input into the production of utility.
4. Page 20: The treatment of contingent valuation is a bit brisk. I was surprised not to see Hausman's book or the NOAA panel report cited. There is a shortly forthcoming *JEP* symposium on this issue.
5. Page 20, at the bottom: "Catastrophic" has two meanings. Catastrophes in the narrow mathematical sense do not necessarily "alter all relationships and necessitate major restructuring of the problem," though catastrophes in the dictionary sense (like a shutdown of the Gulf Stream) would do so. In my view, at least, irreversibilities abound here, and small ones are not cause for alarm.
6. Page 21: The discussion of sustainability in note 1 is too cryptic; refer back to Rawls when you deal with this topic in more depth later.
7. Pages 21-26: The discussion of discounting seems rather longer and more technical than would fit with the rest of the chapter. I have found Broome's *Counting the Cost of Global Warming* to be interesting on discounting, especially its intergenerational aspects. He advocates a zero rate, as does Cline; their arguments at least deserve a cite.

8. Page 23: My sense is that the low productivity growth of the past two decades is "only" an OECD problem -- ?? A cite on this might be useful for non-economists as well as for me. Note 3 also needs some cites.
9. Page 24: You should probably write out the partial derivatives in note 5.
10. Page 26: You should indicate more clearly (probably in a footnote) how the discount rates in the second complete paragraph were derived -- it wasn't clear to me what was being assumed about, e.g., taxes. (I still like my 1976 *JPubEcon* paper on discounting, but I may be alone in this.)
11. Page 26: "No regrets" has nothing to do with risk aversion. Ignoring warming makes sense only if it is impossible or there are no irreversibilities. Since nobody (yet!) argues that warming is likely to be a good thing, the possibility of warming affects means, not just variances, and thus generally has action implications even under risk neutrality. Beat up on "no regrets" all you want (It deserves it!), but for the right reasons.
12. Page 33: Where is the OECD's "polluter pays principle" in this intergovernmental document? Is there a reference for the proposition that Rawls always implies much more progressivity than any utilitarian model? I have some doubts. Broome's book (#7 above) is interesting on population.
13. Page 34, Note 13: How??
14. Page 35: The discussion of taxation here seems a bit too definite for a world in which what seems to matter is the (expected) cost of finding fossil fuels and the oil market at least seems to be heavily influenced by strategic behavior.
15. Page 36: I think aluminum production tends generally to use hydropower, so that carbon taxes may not move it.
16. Page 36, 1.4.2.2.: There have been many studies of the costs of reducing CO<sub>2</sub> from fossil fuels, but there is very little on the costs of other mitigation strategies -- particularly involving other gases. Also, most mitigation studies focus on the developed world, particularly the US.
17. Page 41: Your discussion of the need to "impose commitments" on the developing countries is potentially explosive. **IMPOSE??!!** It is surely clear that if global emissions are to be controlled, theirs will have to be controlled; it is surely also clear that they will not pay for it in my lifetime. They would argue that the rich countries have the obligation to pay for abatement in the poor countries. What is controlled and who has the obligation to pay for control are logically distinct -- and emphasizing that distinction in principle may help you politically.

18. Page 41: I was struck throughout by the lack of cites to Baumol & Oates and other enviro pieces. Also, this is surely a place to tout the US acid rain program.
19. Page 43: "Joint implementation can be viewed as a 'back door' way into tradeable permits" -- this is important and should be elaborated upon for your non-economist audience.
20. Page 46: Technologists (not just environmentalists) always seem morally offended by the universal gap between average practice and best practice. Attempts to legislate away the frictions that cause such gaps usually don't work well, however.
21. Page 50: I very much agree with the conclusion in the first paragraph of 1.5.4.2.2. I'm thus a bit upset that you dismiss it out of hand when you implicitly assume throughout that any serious global regime must involve tradeable permits, not tax harmonization.
22. Page 51: In the first sentence in the second paragraph in 1.5.4.2.4, "most of the next century" seems to imply either that you know that we'll sleep through the first few years after 2000 or that the world will end before the century does...
23. Page 55: Under b), it does not follow from the fact that a permit system cannot be fully efficient that such a system is not optimal unless you have a fully efficient alternative. Under c), as long as demand curves slope down, an industry will oppose a regulation that raises its costs in the short run, even if all firms are under the same regulation. Also, 2) is unclear: giving permits away (the norm empirically, though not in the literature) eases the pain but does not remove opposition -- consider acid rain.
24. Page 57: If climate modelers can come clean about "flux corrections" and other fudge factors, we should come clean about "backstop technologies." (This is the sort of term that begs to be in a glossary.) These are typically inserted into our models without any basis in serious technology forecasting, and their more or less arbitrarily chosen characteristics have a major impact on models' predictions. Backstops are our invention, not the technologists' -- MIT engineers laugh out loud at them.
25. Page 58, top: Carbon tax numbers are almost meaningless to somebody not hip-deep in this literature; percentages of GDP make more sense. If you must include carbon tax numbers, relate them to fuel prices. In the percentage loss numbers that follow, it would be nice to know something about whether costs of, say, stabilization rise or fall over time as a percentage of GDP -- along somebody's long-term forecast.
26. Page 59: Why not discuss the US acid rain program here -- even if the last Administration did invent it? I think b) is a little doctrinaire: full international trading is plainly necessary for full efficiency -- if you go this route -- but it is not obvious that the losses are large if nations trade with each other and use, say, taxes internally. (Do you really

think it is important that households in the U.S. trade *directly* with households in China?) I would add a fourth important lesson: tradable permit systems can deal with equity issues by altering the initial allocation of permits without compromising efficiency. (There were fierce battles over the distribution of SO<sub>2</sub> allowances in 1990; none affected efficiency.) Dealing with equity issues under command and control or tax systems almost inevitably does sacrifice efficiency.

27. Page 60: Your examples of non-greenhouse externalities are one-sided: increasing CO<sub>2</sub> enhances plant growth (is this mentioned anywhere?), and increased SO<sub>2</sub> emissions have a (very short-lived) cooling effect.
28. Page 62: This is a good example of material that is more or less duplicated elsewhere.
29. Pages 71-72: The transition between these pages is abrupt to the point of discontinuity.
30. Page 73: You are critical of the Commerce approach, even though it may not be a bad approximation in a world where finding and extraction are subject to rapid technical progress, but you don't mention that the alternative neglects entirely the expensive processes of discovery and development process. Perhaps I have been overly influenced by my colleagues (including especially Morrie Adelman), but it seems to me that Commerce clearly has the better approximation.
31. Page 80: Removing subsidies is not usually considered "market structure reform"; perhaps you mean "structural reform." Also, the discussion of irreversibilities seems to neglect the awkward fact that there are irreversibilities on both sides of the problem here.
32. Page 81: I'm not sure what the importance of extreme events, with which I agree, has to do with social science. (Forecasting means is hard enough; forecasting variances seems to be beyond near-term hope.)

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IPCC  
cc:SK

August 24, 1994

Professors Joseph E. Stiglitz and José Goldemberg  
Executive Office of the President  
Council of Economic Advisers  
Washington, D.C. 20500  
U.S.A.

Dear Professors Stiglitz and Goldemberg:

I have just been able to review the draft for the IPCC Working Group III Writing Team 1. It is a very good introductory chapter to the report. I thank you for your great trouble.

I have some comments and suggestions, which I send to you with this facsimile. I look forward to seeing you again at Geneva.

Best regards.

Sincerely yours,

Akihiro Amano

Akihiro Amano

## Comments on "WRITING TEAM1: SCOPE OF THE ASSESSMENT"

Akihiro Amano

The present reviewer finds this draft for the Scope Chapter quite illuminating, covering very appropriate topics in an well-organized manner. The following pages present some comments of the reviewer, listed according to the order of the discussions in the draft. He hopes that due considerations will be given to them in the final version.

1. On page 9 and elsewhere, a familiar decomposition equation for greenhouse gas emissions is shown. It shows that changes in GHG emissions can be decomposed into four factors: (a) changes in GHG intensity of energy use, (b) changes in energy intensity of output, (c) changes in output per capita, and (d) changes in population. (The same equation appears on page 100.) A paper by Y. Ogawa summarizes interesting findings within this framework. (Cf. Yoshiki Ogawa, "Analyses of Factors Affecting Carbon Dioxide Emissions Due to Past Energy Consumption Around the World," in Barry P. Jones and Edward F. Wheeler, eds., *Greenhouse Research Initiatives in the ESCAP Region: Energy*, Proceedings of a conference, Bangkok, 21-23 August 1992, ABARE, Australia, 1991.) A reference to this paper might be appropriate.

On page 75, however, it seems that a different decomposition scheme is called for. That is, by focusing on CO<sub>2</sub> emissions the methods of reducing CO<sub>2</sub> emissions are classified into three types: (a) reducing emissions from energy supply (e.g., fuel switching and increased conversion efficiency), (b) increasing end-use efficiency, and (c) shifting consumption patterns away from energy-intensive goods and services. These different approaches suggest that there exists a more general framework which can indicate various important channels through which we can influence CO<sub>2</sub> emissions. For example, we can write

CO<sub>2</sub> emissions

$$= \Sigma_h (\text{Carb. Emis}_h / \text{Prim. Energy}_h) (\text{Prim. Energy}_h / \text{Tot. Prim. Energy}) \\ \times \Sigma_i (\text{Prim. Energy}_i / \text{Second. Energy}_i) (\text{Second. Energy}_i / \text{Tot. Second. Energy})$$

$$\begin{aligned} &\times \sum_j (\text{Second. Energy}_j / \text{Output}_j) (\text{Output}_j / \text{Tot. Output}) \\ &\times \sum_k (\text{Output}_k / \text{Population}_k) (\text{Population}_k / \text{Tot. Population}) \\ &\times \text{Population.} \end{aligned}$$

Thus, a reduction of carbon emissions is possible through

- (1) a reduction of carbon intensity of primary energy  $h$  through technological change or carbon-fixing;
- (2) use of a less carbon-intensive technique for the production of primary energy  $h$  through price inducements;
- (3) a reduction in the share of carbon intensive energy in primary energy supply;
- (4) a reduction of carbon intensity of secondary energy  $i$  through technological change or carbon-fixing;
- (5) use of a less carbon-intensive technique for the production of secondary energy  $i$  through price inducements;
- (6) a reduction in the share of carbon intensive energy in secondary energy supply;
- (7) a reduction of secondary energy intensity for output  $j$  through technological change or carbon-fixing;
- (8) use of a less carbon-intensive technique for the production of output  $j$  through price inducements; or
- (9) a reduction in the share of carbon intensive output in total output through price inducements to demand.

This kind of explanation can illuminate important nodes upon which we can operate, such as (a) energy conversion or energy end-use; (b) choice of techniques or technological change; (c) exogenous effects or endogenous, price-induced effects; and (d) supply-side (choice of production methods) or demand-side (composition of inputs or outputs).

2. The last sentence of 2) on page 17 seems to neglect the experiences in Nordic countries after 1990. Or, does it mean to say "an *international* carbon-tax scheme"?

3. The content of the third paragraph of 3) on page 17 does not seem to fit the title of this sub-section. It seems to be better included under 1) on the previous page.

4. Section 1.3 on page 19 attempts to cover important cost items of global warming. As I summarized in my earlier contributing memorandum to the Writing Team 1, Fankhauser and Cline also estimated the magnitudes of various damage items other

than covered in this draft. The items not covered in this draft are, for example, migration, Hurricanes, Construction, Leisure activities, Urban infra-structures, Air pollution, etc. There seems to be no reason to disregard them, even though they need not be mentioned item by item.

5. On page 22, the first line of 1.3.1.3 reads, "A warmer climate implies both northward movement of forests and changes in forest composition." I am afraid this is a view of the people living in the northern hemisphere.

6. In Section 1.3.3 on pages 27-28, irreversibilities are treated as something parallel to catastrophic events. However, I understand that global warming itself is an irreversible phenomenon within a human time scale, because of cumulative effects of GHGs with a quite long time-lag. I should like to have the role of irreversibilities in the present context a little bit more clarified.

7. The sentence starting at the second line of page 29 reads, "For intertemporal planning, this implies that consumption per head should be the same for all generations." I wonder if this statement is correct. Consider a developmental path along which per capita income at the highest income bracket remains the same, whereas the per capita income level of the poorest bracket improves over time. Suppose also that income distribution ultimately becomes perfectly equal. This kind of situation is quite consistent with the max-min criterion, even though consumption per head would not naturally be the same for all generations except at the steady-state.

8. The draft quotes a view that justifies discounting the future on a basis of the possibility that future generations may not exist (the first paragraph on page 31). There are a couple of arguments, however, against such a view advanced by Clive Spash (see Clive L. Spash, "Economics, Ethics, and Long-Term Environmental Damages," *Environmental Ethics*, Vol. 15, No. 2, Summer 1993, pp. 117-132). It would be fair to mention this literature as well.

9. In discussing the sharing of tax burdens, it is stated, "As we have noted, it is possible to ascertain the economic benefits of mitigation, and these are likely to be quite unequally distributed." (The first paragraph on page 45.) There is a question, however, whether people in developing countries take the effects of mitigation as benefits to them, as they might consider that the mitigation simply restores the old

status quo which is naturally to be expected. This is the so-called initial point problem to be addressed somewhere.

10. In the middle of page 45, the implications of population policy for income distribution policies are discussed, and, in relation to that, the question of initial allocation of tradable permits is taken up. However, in the section where the tradable permit system is the main subject, the initial allocation has not been discussed. Since the discussion above only relates to the population problem, it seems to be necessary to give a full exposition concerning pros and cons of allotting or bidding or whatever methods of allocating the initial emission quotas somewhere. Or, we can explicitly mention that we leave it to other writing teams.

11. The last sentence in the first paragraph of page 48 reads, "Analyzing the optimal intertemporal structure of taxes, to minimize long run ambient levels of greenhouse gases, taking into account both intertemporal substitution and substitution across energy sources, is a complicated technical issue, that to date has not been adequately analyzed." Although much depends on what "adequately analyzed" means, there are many works such as those by Prof. Alan Manne and Dr. Richard Richels that addressed this problem squarely.

12. The word "emissions" in the second line from bottom of paragraph 3 on page 50 should read "concentration."

13. In the middle of the third paragraph on page 51, it is stated that countries with northern climate are likely to find costs of adaptation particularly small. Is this true in view of the fact that the increase in average temperature tends to be higher, the higher the latitude?

14. Discussions on climate engineering are always followed around by some sort of uneasiness (at least to me), because they seldom accompany discussions on environmental assessment of engineering options themselves. If they have other environmental costs (both direct and indirect) with unknown risks, it would be dangerous to build a feeling that they are something that one can rely upon when other options prove to be unexpectedly costly.

15. In discussing the United Nations Framework Convention on Climate Change, the draft touches upon the standard views concerning equity in a fairly abstract manner (the first paragraph on page 56). Readers will find it difficult, however, what "earlier discussions on principles of public finance" really mean in the present context. Discussions could be more explicit.

16. "Table 1" in the second line from the bottom of page 56 is missing. Are CITES and Basel Convention also included in this table?

17. In Section 1.4.6.4 the implications of international trade for the global and local impacts of costs of warming are discussed. This is, of course, an important topic. On the other hand, international trade in forest products may have been encouraging deforestation because international prices of forest products do not fully reflect their social costs. In order to have international prices reflect true social costs, importing countries could introduce import charges on tropical woods, and transfer the revenue to the exporting countries to finance environmental programs. Higher prices in importing countries can limit consumption, and lower international prices will limit excessive deforestation. This kind of discussion should be included somewhere (possibly in Section 1.8.5.3 on page 106).

18. References would be useful for the last point mentioned in the first paragraph on page 64.

19. The argument in the third paragraph on page 64 depends on an implicit assumption that the timing of low-carbon or no-carbon energy sources becoming relatively cheaper is determined exogenously. If it is dependent upon control variables of policy options, i.e., if higher prices of carbon emissions now can hasten the introduction of low-carbon or no-carbon energy sources, then the optimal delay of emission limitation would become shorter.

20. There seem to be two sources of irreversibilities in relation to Section 1.5.3.1 on page 67: first, the fact that emission control investments involve sunk costs, and second, the fact that no action now leads to a higher atmospheric concentration of GHGs which after a long time-lag must bring about global warming. These two irreversibilities work in opposite directions with each other.

21. In the discussion of Section 1.5.3.3 on page 68, it is not quite clear what the phrase "direct expenditures on emission reductions" really implies. Just as we can argue whether direct regulations are more resource-efficient in inducing technological innovation than economic instruments, we can compare the resource-effectiveness of R&D expenditures with economic instruments (i.e., we compare the amount of resources devoted to R&D and economic costs involved in adopting economic measures with due allowance for discounting). Then, the efficient policy would not be of an either-or style, but would involve both at appropriate rates.

22. A sentence in the third paragraph on page 69 reads, "For example, the goal of stabilizing emissions would cost far less if averaging is allowed among different years along the path than if emissions must not rise in any year; to the atmosphere, what matters at any given time is total concentrations, not the emissions path." Two cautions are in order: first, there exists an uncertainty that postponed emission reduction efforts will not be carried out under expected conditions; second, when the time period of averaging is very long, benefits and costs can accrue to different generations. These two considerations would put certain constraints to the use of averaging.

23. Again, the problem of irreversibilities appears in Section 1.5.4.1.3 on page 69. Here, it is stated that in the absence of threshold damage effects, the dominant irreversibility is not in the climate system, but rather in commitments to capital stocks to control emissions. We would like to know the opinions of scientists on the importance of threshold damages. Would it be possible to ask some help from people in the Working Group II?

24. The argument in the last paragraph on page 71 presupposes an independent action of individual countries. It seems that emphasis should also be given to the importance of international approaches. Portfolio of policies to complement or to support those approaches might be quite different from one taken from an individual country point of view.

25. Another question concerning "no regrets policies" discussed in the last paragraph on page 72 would be whether they are enough (or conversely whether they would become too much if pursued all at once).

**26.** In 8th line of the third paragraph on page 76, the word "permits" should read "permit prices."

**27.** In 2nd line of the fourth paragraph on page 90, "industrial" should read "household."

**28.** The definition of "Sustainable Development" by the Brundtland Commission presented on page 99 appears insufficient by itself. One of the important elements of SD emphasized by the commission is intra-generational equity and especially the eradication of poverty. The last sentence in Section 1.8.5.4 on page 109 states exactly this.

**29.** The third and fourth paragraphs on page 106 just seem to highlight the usefulness of Joint Implementation in attaining "leapfrogging" earlier development paths, in decoupling energy use from economic growth, and in reducing deforestation in developing countries.

IPCC LEAD AUTHORS MEETING  
Geneva, Switzerland  
September 8-10, 1994

**More Minor Comments**

1. Chapter 2 on "Benefit Cost Analysis" is well balanced and a technically strong discussion. Is it necessary to devote so much attention to multicriteria analysis, almost 10% of text in the chapter? The summary is well crafted and emphasizes the importance of tradeoffs between equity and economic efficiency; no mention of MCA is made in the summary.
2. Chapter 3 has a thorough treatment of damage estimates, but estimates provided may be misleading because the degree of uncertainty associated with climate change damages is not conveyed. An evaluation of categories of damages that are most uncertain is needed. The techniques used to generate these estimates should be discussed more fully. Perceptions of damages from climate change drive the international debate and as such should be buttressed with as much information as possible about different factors influencing range of estimates. (Tables 3.4, 3.5, 3.6, and 3.8 should show confidence bounds).
3. The caution that should be observed in transplanting OECD instruments to LDCs should be more fully assessed in the chapter on policy instruments.



# INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE



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## MEMORANDUM

TO: Dr. Joseph Stiglitz

FROM: Dr. Erik Haites *Erik*

CC: Dr. Sally Kane

RE: Attached Materials

DATE: September 3, 1994

Here are the Work Plan from Montreal and the Work plan for Seoul. Unfortunately, we were not able to locate the list of lead authors and reviewers nominated by the U.S. - my sincere apologies for this inconvenience.

See you in Geneva.

# **Preliminary Agenda for Lead Authors Meeting**

**Seoul**

**September 6 - 8, 1993**

**Monday, September 6 - Chair: Dr. Hoesung Lee, Co-Chair, WG III**

- |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 8:00 - 8:30   | Registration                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 8:30 - 9:00   | Welcome - Dr. Hoesung Lee, President, Korea Energy Economics Institute                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 9:00 - 10:20  | IPCC Assessment Process: Dr. N. Sundararaman, Secretariat, IPCC<br>Dr. R. Odingo, Vice-Chair, WG III<br>Dr. T. Hanisch, Vice-Chair, WG III                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|               | <ol style="list-style-type: none"><li>1. History and function of the IPCC</li><li>2. Scope of the Second Assessment Report</li><li>3. Mandates of Working Groups I, II, and III</li><li>4. Audiences for IPCC Second Assessment Report:<ul style="list-style-type: none"><li>* Working Group reports and executive summaries</li><li>* summaries for policymakers</li><li>* synthesis report in response to INC mandate: Article 2</li></ul></li><li>5. Philosophy of IPCC assessments, ie., peer-review process (expert and governmental), geographic representation, minority views</li><li>6. Relationship of IPCC assessments to international ozone and biodiversity assessments</li></ol> |
| 10:20 - 10:40 | Refreshments                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 10:40 - 12:00 | Logistical Arrangements for the Working Group III Report: Dr. Erik Haites, Head, Technical Support Unit, WG III                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|               | <ol style="list-style-type: none"><li>7. Roles, responsibilities, and deliverables of convening lead authors, lead authors, contributors, and working group chairs</li><li>8. Timetable for Working Group III</li><li>9. Length of report, chapters, and sections</li><li>10. Procedures for review and acceptance of the report</li></ol>                                                                                                                                                                                                                                                                                                                                                      |
| 12:00 - 13:30 | Lunch                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

- 13:30 - 15:00      Content of the Working Group III Report: Dr. Erik Haites
11.    Content of the SAR and of individual chapters
  12.    Division of the work among writing teams
  13.    Overlaps among writing teams and among working groups
  14.    Use of contributing authors
- 15:00 - 15:30      Refreshments
- 15:30 - 17:00      Content of Working Group III Report: Dr. Erik Haites
15.    Working Group III workshops
  16.    Common socio-economic and other parameters
- 18:00 - 19:00      Welcome Reception  
Host: Dr. Hoesung Lee, President, Korea Energy Economics Institute

**Tuesday, September 7**

- 8:30 - 17:00      Separate meetings of writing teams
1.    Select/confirm convening lead author
  2.    Review scope of writing assignment to identify potential gaps and overlaps
  3.    Discuss work assignments and schedule for writing team members
  4.    Discuss potential contributing authors
  5.    Discuss workshop content, format, and organization (if appropriate for the working team)

**Wednesday, September 8 - Chair: Mr. James Bruce, Co-Chair, WG III**

- 8:30 - 17:00      Plenary Meeting to Discuss Issues and Overlaps: Mr. James Bruce, Co-Chair, WG III
1.    Questions raised by writing teams
  2.    Review of schedule and workshops
  3.    Liaison with Working Group I and II
  4.    Next deadline

# **The Intergovernmental Panel on Climate Change (IPCC)**

## **What is IPCC?**

IPCC is an intergovernmental organization that assesses the current state of science - all types of science - as it related to climate change. IPCC does not actually do any science - it assesses what is known and provides advice and counsel to governments through its parent bodies, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP).

## **The history of IPCC**

With the formation of the World Climate Programme after the first World Climate Conference in 1979, WMO and UNEP signalled their determination to pursue climate and climate change related studies. As interest and awareness of the issue of climate change heightened in the international community, it became clear that there was a need to make available to individual governments information on the subject of climate change so that they could formulate effective policies.

The idea of the IPCC was first suggested in 1987 and endorsed by the WMO Executive Council and the UNEP Governing Council at their meetings in 1988. The IPCC was established in 1988 and told to report to these governing bodies on the state of knowledge of climate change science and the environmental and socio-economic impacts of climate change. It was also tasked with formulating response strategies to deal with climate change.

## **What has IPCC achieved so far?**

The first reports of the IPCC were issued in August 1990. The work of the Panel had been carried out by three working groups, one on science, one on impacts, and one on response strategies. Each working group produced a report which, together with an overview and a summary for policy makers, constituted the IPCC First Assessment Report. This report has now become a standard reference of work that is widely used by policy makers, scientists, and others.

Anticipating a need for the most current information on climate change to support the ongoing negotiations on the Framework Convention on Climate Change, the IPCC requested its working groups to update the First Assessment Report. The resulting IPCC Supplement was completed in February, 1992.

## **What is the IPCC doing now?**

In November 1992, the IPCC was restructured into three new working groups, each of which was asked to provide input to a Second Assessment Report to be produced in 1995. Working

Group I on science was left unchanged and continues to build on the work described in the First Assessment Report. The new Working Group II will deal with assessing the impacts of climate change and developing response strategies. Working Group III is completely new and will deal with the socio-economics of climate change, the costs and benefits of mitigation and adaptation to climate change and to assess, if necessary develop, new emissions scenarios.

### **What is Working Group III doing?**

Working Group III has a mandate to deal with issues related to climate change that cut across the mandates assigned to other working groups, and in particular with the sensitive and relatively new area of the socio-economics of climate change. The Working Group will also be examining and assessing the validity of various greenhouse gas emission scenarios. At the reorganizational meeting of the IPCC in November, 1992, Working Group III was asked to prepare technical assessments of the socio-economics of impacts, mitigation and adaptation to climate change and to consider and develop, as necessary, a range of future emissions scenarios for inclusion in the IPCC Second Assessment Report due in 1995.

### **How is Working Group III organized?**

All member states of the World Meteorological Organization and the United Nations Environment Programme are eligible to participate in the work of the Working Group III. This participation could be in any and all activities outlined in the workplan and, in particular, could involve having individuals from those states participate in the authorship or review of the material prepared for the Second Assessment Report. This activity will be overseen and co-ordinated by the Working Group III Bureau, which consists of Co-chairs from Canada and Korea and Vice Chairs from Norway and Kenya.

Technical and secretariat support for the Working Group will be provided by Technical Support Unit (TSU) located in Environment Canada.

# Work Programme of Working Group III

## SCOPE OF WORK

It is proposed that the efforts of the newly reconstituted Working Group III of IPCC be carried out in the manner described in this work plan. Attached is a outline of the themes to be considered in the Working Group III Second Assessment Report (SAR).

The Working Group will, in accordance with its Terms of Reference, prepare a comprehensive technical assessment of the socio-economics of mitigation of climate change, the impacts of climate change, and adaptation to climate change over both the short and long term and at the regional and global levels. This contrasts with the work of Working Group II, which will be assessing the economic impacts on particular economic sectors at a more local level. Nevertheless, considerable collaboration between the two working groups will be necessary.

As reflected in United Nations General Assembly document A/AC.237/30 the chair of the Intergovernmental Negotiating Committee (INC) for the Framework Convention on Climate Change has requested that IPCC prepare, in time for the first meeting of the Conference of the Parties to the Convention (COP), "an evaluation of current scenarios of greenhouse gas<sup>1</sup> emissions and removals by sinks." The proposed time line addresses this request and assumes that the first meeting of the COP will take place in the spring of 1995. If this turns out not to be the case, the timing of activities shown that relate to the evaluation of scenarios would be adjusted accordingly. This element of the work is expected to build heavily on the work of the 1992 IPCC Update, which contained six greenhouse gas emissions scenarios. It is suggested that this work be carried out by examining the major assumptions made in developing the original scenarios and, based on whatever new information is available, assessing the validity and appropriateness of those assumptions and making recommendations on the need for updated or new scenarios. If it is agreed that new scenarios are needed, actions will have to be taken to develop them for the Second Assessment Report. The work on responding to the INC request will be closely coordinated with that on the same issue for the SAR by involving the same group of contributors. The IPCC Bureau is seeking clarification of the other elements of the INC's request, which raise cross-cutting issues which Working Group III may need to consider.

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<sup>1</sup>Throughout this document, the term "greenhouse gas" is as defined in Article 1 of the Framework Convention on Climate Change.

In evaluating scenarios and in developing its scientific and technical assessment, the Working Group proposes to undertake a number of specific activities, which are described in this work plan.

## **PRINCIPAL CONSIDERATIONS**

The work of the Working Group will be carried out with the following considerations in mind:

- It will place the socio-economic perspectives of climate change in the context of sustainable development. In particular, and in accordance with the Framework Convention on Climate Change, the work of the Working Group will be comprehensive, cover all relevant sources, sinks, and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors.
- Institution and endogenous capacity building in developing countries will be integrated into the work programme.
- The work of the Working Group will not stand in isolation from other IPCC activities. Consultation and coordination with the activities of the other Working Groups will be carried out to the greatest extent possible.
- The work will, to the greatest extent possible, build on existing work, recognizing that the IPCC role is one of assessing existing knowledge for the Second Assessment Report.
- The activities of the Working Group will take into account the special situations of developing countries and economies in transition and will be carried out at a pace and be of a type that allows for the full involvement of these countries.
- The work will be carried out in as cost-efficient a manner as possible, bearing in mind the limited resource capacity of IPCC and all member countries. This implies close cooperation with other bodies working in the same fields in order to avoid duplication of effort.

## **ACTIVITIES OF THE WORKING GROUP**

The Working Group will prepare a report comprising its contribution to the IPCC Second Assessment Report and containing a technical assessment of the state of knowledge of the socio-economics of climate change mitigation, adaptation, and impacts, taking into account the factors described in part (a) of the Terms of Reference of the Working Group. It is proposed that the structure of this report follow the proposed outline of the themes shown in Annex B.

The Working Group will also prepare a report, in time for the first meeting of the Conference of the Parties to the Convention, on the validity, appropriateness, and utility of existing net greenhouse gas emissions scenarios based on the factors described in part (b) of the Terms of Reference of the Working Group. An update of this report, including any new scenarios that it is agreed should be developed, will be included in the Group's contribution to the IPCC SAR.

The preparation of both reports would be carried out as follows, using the dates indicated in the time line in accordance with the procedures described in the IPCC proposal for procedures for preparation, review and adoption of IPCC reports:

- The Bureau of the Working Group will ask governments and participating organizations to identify experts in their countries who could be involved as part of teams of lead authors, contributors, and expert reviewers for each report. Governments will also be asked to identify IPCC contacts for the purpose of coordinating later review by their governments.
- The Bureau of the Working Group will ask governments to suggest themes, dates, and locations for IPCC workshops that could be held to review the scenarios and the scientific and technical work that is being assessed, bearing in mind the principal considerations noted above and the IPCC workshop policy. For reasons of economy and to avoid overlap and duplication, the Bureau will coordinate with other IPCC Working Groups and international organizations in conducting these workshops.
- Based on the suggestions of governments and participating organizations, the Bureau will meet with the Chair of IPCC and possibly with some of the experts identified, to decide on the detailed contents of each section of the reports, assign teams of lead authors for each section, and decide on which workshops should be held. The Bureau will also decide, from the perspective of Working Group III, whether IPCC co-sponsorship should be extended to other workshops, seminars, or meetings.

- Lead authors will undertake preparation of the first drafts of each section and submit them to the Co-chairs, bearing in mind the tasks and responsibilities identified for contributors and themselves.
- The first drafts will be circulated for peer review to the specialists. Referenced material will be made available by the Co-chairs, who will collect the comments of the reviewers and make them available to the lead authors. Lead authors will then revise the drafts and, if time permits in the schedule indicated in the time line, Co-chairs will circulate the revised drafts again for review.
- The revised drafts will be sent to governments and participating organizations for review.
- The summary for policy makers will be approved at a meeting of the Working Group in Plenary session and adopted by the Panel.

## **THEMES TO BE CONSIDERED IN THE WORKING GROUP III SECOND ASSESSMENT REPORT**

### **PREFACE**

The preface will outline the mandate and terms of reference of the working group, describe how it went about producing the report, what the intended audience of the report is, and the purposes for which the report should be used. The preface will note that none of the tasks shall involve the Working Group making policy judgements. Each chapter will also place the socioeconomic perspectives of climate change in the context of sustainable development. The working group should analyze the issues as broadly as possible recognizing the Rio Declaration on Environment and Development, Agenda 21 and in particular the Framework Convention on Climate Change, as adopted.

### **EXECUTIVE SUMMARY**

### **SUMMARY FOR POLICY MAKERS**

### **THE SECOND ASSESSMENT REPORT**

The SAR consists of three parts. The first part addresses the scope of the assessment and the remaining two parts address the mandate of the Working Group.

### **PART I: SCOPE OF THE ASSESSMENT**

This assessment will include, *inter alia*, the socio-economic perspectives of climate change, the nature of the interactions between economic activity and climate change, and emissions scenarios. The assessment will address the global nature of the problem, taking into account particularly the circumstances of countries vulnerable to the impacts of climate change and to the impacts of response measures. In addition, it will cover a scientific evaluation of the appropriateness of the methodologies used for the analysis, including the socio-economic assumptions underlying existing modelling frameworks, its relations to observable data such as national accounts figures (GDP). To fulfil the scope of the analysis, existing supplementary indicators (such as the Human Development Index developed by the UNDP) will be assessed.

## **PART II: THE SOCIO-ECONOMICS OF IMPACTS, ADAPTATION, AND MITIGATION OF CLIMATE CHANGE**

The mandate of the Working Group states that it should undertake “Technical assessments of the socio-economics of impacts, adaptation and mitigation of climate change over both the short and long term and at the regional and global levels. The work plan should, *inter alia*, consider the following topics: top-down and bottom-up economic modelling . . . ; the evolution of technological change; methods for risk assessment; methods for the generic assessment of response instruments . . . .” For each theme in this part, a key question to be answered that addresses this section of the mandate has been identified.

### **CHAPTER 1: SOCIO-ECONOMIC FRAMEWORK FOR DECISION-MAKING**

Key question: How do we take socioeconomic factors into account when making decisions about the climate change issue? The issues addressed under this theme will include, *inter alia*:

#### **Socio-economics of Climate Change in Relation to the Need for Sustainable Development**

Decision-making under uncertainty:

- The socio-economic factors to be considered when making decisions in the short and long term.

Risk assessment including, *inter alia*, discussion of the following questions:

- What methods can be used to assess risk and what levels of confidence can be attached to such methods?
- What are the perceptions of and responses to risk?
- What are possible response measures?
- What are the risks of inaction and of undertaking “no-cost” or cost-effective “low-cost” response measures and of taking more far-reaching response measures? (This section should take into account sequential decision-making, portfolio analysis, benefits and costs of taking action early versus late, and the long-term implications of short-term decisions).

Methods and applications of cost-benefit analysis including, *inter alia*:

- Concepts such as opportunity costs, trade-offs, marginal costs and marginal benefits, limitations of cost-benefit analysis and consideration of alternative methodologies, and the value and importance of non-market factors such as biodiversity, long-term discounting, public perceptions, social well-being, thresholds, and irreversibilities.

Equity considerations including, *inter alia*:

- Varying contributions between regions for past emissions, the “free rider” problem, inter-regional and inter-generational equity, and the question of the time lags between the incurring of costs and the accruing of benefits.

The value of information including, *inter alia*, discussion of the following:

- Significant efforts are being undertaken every year on global climate research in the area of natural sciences. Where are the highest potential payoffs for likely future decisions? What are the most critical uncertainties, including scientific uncertainties? What kinds of research can reduce them and reinforce society’s ability to confront uncertainty? What is the value of this scientific research in terms of its ability to describe the linkages between the natural sciences and socio-economics? What are the predictable trends of scientific and technical progress in efficiency of use of different energy types with respect to carbon intensity and in the adaptation of species to new climatic situations?

Sociological considerations.

## **CHAPTER 2: ASSESSING THE BENEFITS OF RESPONSES TO CLIMATE CHANGE**

Key question: What methods exist for assessing the economic and social benefits of action and inaction? The issues addressed under this theme will include, *inter alia*:

Methods for estimating benefits:

- The status-quo option. What would be the socio-economic impacts in the absence of any action to deal with the problem of increasing concentrations in the

atmosphere of greenhouse gases and aerosols? How would the benefits vary with different degrees and timing of actions to limit climate change?

- Methods based on market impacts. For example, adaptation through trade, market agents, migration of population, and economic activity.
- Methods based on non-market impacts such as ecological and social impacts.

Major issues in estimating benefits:

- An assessment of the state of knowledge related to issues involved in estimating benefits, including, *inter alia*; distinguishing between short-term and long-term impacts; the relationship of impacts to the degree, timing, and predictability of climate change; techniques for valuing impacts on ecosystems; hard-to-define values such as aesthetics, impacts on land use, impacts on biological diversity and other environmental problems and social well-being; and modelling limits dealing with thresholds, irreversibilities, and time horizons.

Methods for estimating the costs of human adaptation.

### **CHAPTER 3: EVALUATING THE COSTS OF MITIGATION OF GREENHOUSE GAS EMISSIONS BY SOURCES AND REMOVAL BY SINKS**

Key question: What are economic, social, and environmental contributions to understanding, both conceptually and empirically, the costs of mitigation of greenhouse gas emissions? The issues addressed under this theme will include, *inter alia*:

- Variables for measuring costs. A discussion of costs from a long-term perspective, including, *inter alia*, measures such as social welfare, health and other environmental effects, real incomes, trade, productivity, and income transfers among regions.
- Assumptions in empirical analysis including, *inter alia*:
  - Modelling assumptions including uncertainties and ranges;
  - Technological change;
  - Macro-economic and demographic assumptions such as productivity growth, population and labour force change, and structural change in economies;

- Consumption patterns;
  - Fuel supply schedules, including the potential of renewable fuel and energy technologies, demand and supply elasticities, and exchange rates; and
  - Land use.
- Policy instruments for domestic and regional use including, *inter alia*:
    - Economic instruments such as taxes, subsidies, tradeable permits, tradeable absorption obligations, user charges, and deposit-refund schemes;
    - Regulatory instruments including technology-based and performance-based; and
    - Other instruments such as land use programmes and public awareness and education programmes.
  - Modelling methods: A description of various types of models (e.g., “top-down” and “bottom-up”) according to purpose, and a discussion of their relative strengths and weaknesses, including, *inter alia*, a discussion of data limitations and limitations of model applications, the reasons for differences in the predictions made by them and ways to evaluate those results, and the integration of modelling techniques (e.g., bottom-up studies of new technologies). The appropriateness of the modelling methods should be discussed in relation to the problems of developing countries and should reflect the concerns and special conditions of developing countries. The models should include as many different policy instruments as possible. Possible other issues include dynamic versus static models, econometric versus parametric models, perfect versus limited foresight in models, the treatment of international trade, model time horizons, and how various modelling techniques could be integrated. Different policy options will be used to derive model outputs.
  - Model comparisons: A comparison of results including, *inter alia*, distributional impacts and reasons for differences, the impact of response measures by industrialized countries on developing countries, and a survey of the degree of dependency of countries on the production, exportation, and consumption of fossil fuel and associated energy-intensive products. A special effort will be made to incorporate developing country studies.

- Major issues of cost estimation: Potential topics include, *inter alia*, unilateral versus multilateral responses, with trading allowed or not; the timing of responses and the amounts of reductions; and other matters such as eliminating subsidies and recycling revenues.
- Topics for future work: A discussion of the types of future research needed such as the integration of bottom-up studies into macroeconomic and general equilibrium models, research into the impacts of sustainable development practices, and identification of future work needs, particularly regarding the needs of developing countries.

## CHAPTER 4: GENERIC ASSESSMENT OF RESPONSE OPTIONS

Key question: What methods exist for assessing the net costs and effectiveness of different response options in a comprehensive manner?

The discussion of cost evaluation in each of these sections should incorporate a discussion of net costs and should include complementary socio-economic effects, both negative and positive, on such elements as GDP, employment levels, the balance of trade, economic structure, and the environment. The issues addressed under this theme will include, *inter alia*:

- Adaptation options: A discussion of different options for developed countries, developing countries, and those with special circumstances (e.g., low-lying, arid, and countries in transition).
- Mitigation options: A discussion of mitigation measures which should reflect, for example, the concept of comprehensiveness (all greenhouse gases, sinks, and sectors), including, *inter alia*, reducing emissions by correcting market and government policy shortcomings, eliminating subsidies and barriers, dissemination of information and technology cooperation, and introducing economic instruments.
- Methods for assessing the effectiveness of options including, *inter alia*, the use of models and the extent to which models incorporate the full range of options and conditions.
- Comparison within and between mitigation and adaptation response options. The comparison should include, *inter alia*, their cost-effectiveness, their influence on innovation and promoting environmentally sound technologies, their influence on

other environmental matters, their ease of administration, monitoring, and enforcement, their capacities to cope with uncertainties, their data requirements, and equity and sustainable development considerations.

- Technological change. A discussion of the factors determining technological change as a driving force for, as well as a way to control net greenhouse gas emissions (e.g., renewable energy, low-energy systems, carbon sequestration, etc.), taking into account the penetration, diffusion, and transfer of technology and the different dynamics in developed and developing countries; and which of these factors can be influenced and how.
- Internationally coordinated instruments. A discussion of mechanisms such as "joint implementation," carbon leakages (shifts of carbon-intensive activities) linked to demographics, consumption patterns, and economic growth of industrialized and developing countries, assistance and trade aspects, and the possibilities and difficulties of internationally coordinated instruments.

### **PART III: EMISSIONS SCENARIOS**

#### **CHAPTER 5: CONSIDERATIONS OF CONSISTENT SCENARIOS**

The mandate of the Working Group states that it "should consider . . . a range of internally consistent scenarios for future emissions based on reasonable economic, demographic and technological projections." With this in mind, the key question to be answered is, "Which issues and uncertainties about key variables may critically affect future net greenhouse gas emissions and aerosol concentrations?" The issues addressed under this theme will include, *inter alia*:

- Types of models for scenario development and their application.
- The assumptions made in developing existing scenarios. A discussion of the key assumptions concerning, *inter alia*, economic growth, demographics, consumption patterns, technological change, energy prices and supply, international trade flows, distributional issues, social change, sustainable development, land use, and non-greenhouse gas environmental constraints such as acid rain.
- The relative importance and sensitivity of different variables in determining future emissions and sinks.
- The relationships among key variables.

- The sensitivity of these variables, most notably to government actions.
- The relationship of scenarios to the emissions inventory methodology developed by Working Group I. A number of country studies are being completed and could make a useful contribution to scenario analysis.
- The degree of uncertainty, including, *inter alia*, a discussion of the following questions:
  - What are the gaps and uncertainties in available knowledge about these factors and their influences on emissions?
  - What does the extent of this uncertainty tell us about the validity of current scenarios? How do existing IPCC scenarios compare with other existing scenarios? Are new scenarios required?
  - What are likely to be the impacts of this uncertainty on short- and long-term future emission scenarios?
- Model structures for analysis of scenarios, including, *inter alia*, a discussion of the following questions:
  - How useful are current models in terms of their regional detail, solution algorithms, and data?
  - What are the characteristics of current models?
  - What is the sensitivity and flexibility of models to technical and structural assumptions?
- The appropriate uses, capabilities, and limitations of emissions scenarios in scientific assessment and policy-making.
- An assessment of the need for future work on scenarios to serve the needs of climate modelling, planning of response measures, and provision of information to the Conference of Parties to the Framework Convention on Climate Change.

# **Tasks and Responsibilities for Lead Authors, Contributors, and Expert Reviewers of IPCC Reports and IPCC Government Contacts**

## **Lead Authors**

**Functions:** To produce designated sections addressing items of the work programme on the basis of the best scientific and technical information available.

**Comment:** The essence of the lead authors' task is synthesis of material drawn from the peer reviewed literature, generated at workshops or submitted by contributors. Lead authors may not necessarily write original text themselves, but they must have the proven technical ability to develop text that is scientifically sound and that faithfully represents, to the extent that this is possible, contributions by a wide variety of experts. the ability to work to deadlines is also a necessary practical requirement.

Lead authors will typically work as small groups which have responsibility for ensuring that the various components of their sections are brought together on time, are of uniformly high quality and conform to any overall standards of style set for the document as a whole.

The task of lead authors is a demanding one and in recognition of this their names should appear prominently in the final report. During the final stages of report preparation, when the workload is often particularly heavy and when lead authors are heavily dependent upon each other to read and edit material, and to agree to changes promptly, it is essential that the work should be accorded the highest priority.

Principles Governing IPCC Work require Lead Authors to record views which cannot be reconciled with a consensus view but which are nonetheless scientifically valid.

Lead authors may convene meetings with contributors, as appropriate, in their preparations of their sections and to suggest any workshops in their relevant area to the Working Group co-chairs.

## **Convening Lead Authors**

In addition to the duties of a lead author, the convening lead author coordinates the efforts of the writing team to ensure that all issues are

comprehensively addressed and that reports and revisions are completed on schedule.

## **Contributors**

**Function:** To prepare technical information in the form of text, graphs or data for assimilation by the lead authors into the draft section.

**Comment:** Input from a wide range of contributors is a key element in the success of IPCC assessments, and the names of all contributors should be acknowledged in the reports. Contributions are sometimes solicited by Lead Authors but unprompted contributions are positively encouraged.

Contributed material may be edited, merged and if necessary, amended, in the course of developing the overall draft text.

## **Expert Reviewers**

**Function:** To comment on the accuracy and completeness of the scientific/technical content and the overall scientific/technical balance of drafts.

**Comments:** Expert reviewers will comment on the text according to their own knowledge and experience. They may be nominated by governments, national and international organizations, Working Group Bureaus, Lead Authors, and contributors.

## **Government Review**

**Function:** To comment on the accuracy and completeness of the scientific/technical content and the overall scientific/technical balance of drafts.

**Comment:** Government review will typically be carried out within and between a number of Departments and Ministries. Countries may convene their own seminars and workshops to review draft reports and advise on comments. For administrative convenience, countries should nominate a single IPCC Government Contact.

# **Procedures for Preparation, Review, and Acceptance, of IPCC Reports**

## **Organization of Work**

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

At the earliest opportunity, Working Groups should inform all IPCC countries and participating organizations about who the lead authors are and the areas they are covering. Experts who wish to contribute material for consideration in the first draft should submit it directly to the lead authors. Contributions should be in the form of text specifically written for the draft report and supported as far as possible with references from the peer-reviewed and internationally-available literature, and with pre-prints of any unpublished material cited.

Lead authors will work on the basis of these IPCC contributions, the peer-reviewed and internationally-available literature including scientific and technical publications prepared by national governments and scientific bodies, the latest reports from researchers that can be made available in pre-print form for IPCC review, and IPCC supporting material.

In preparing the first draft, and at subsequent stages of review, lead authors should clearly identify disparities of view for which there is significant scientific or technical support, together with the relevant arguments.

## **Review by Experts**

First draft reports should be circulated by Working Group co-chairs for review by experts. The review circulation should include:

- specialists who have significant publications in particular areas;
- specialists on the IPCC lists maintained by the Working Group co-chairs;
- IPCC countries and participating organizations;
- specialist reviewers nominated by appropriate international scientific and technical organizations (eg. WMO, UNEP, ICSU, Third World Academy of Science, FAO, IOC, World Bank, Regional Development Banks, OECD).

The Working Group co-chairs should make available to reviewers on request all material referenced in the document being reviewed which is not available in the international published literature.

Comments by reviewers should be made available to the appropriate lead authors. Working Group co-chairs should arrange for a full record to be kept of all comments received and, upon request, the comments should be made available to contributors and reviewers.

Lead authors, in conjunction with Working Group co-chairs, are encouraged to supplement the draft revision process by organizing a wider meeting with principal contributors and reviewers, if time and funding permit, to pay special attention to particular points of assessment or areas of major differences.

The time schedule allowed for return of review comments will be constrained by the IPCC work schedule, but normally should not be less than six weeks, except when special circumstances permit only one month. More time may be required for some material. If time allows, a revised draft incorporating comments, together with any appropriate summary, should be circulated again for review by experts.

### **Review by Governments**

A revised draft should be distributed by Working Group co-chairs to governments through the designated IPCC government contacts, and to all the original contributors and reviewers.

Governments should send one integrated set of comments for each Working Group report to the appropriate Working Group co-chairs through their IPCC government contacts. they may wish to organize their own mechanisms for consulting experts in preparing their responses.

To facilitate government review, non-government reviewers should send their further comments to Working Group co-chairs with a copy of their appropriate government IPCC contact.

Contributors and reviewers should make full use of the draft and revised report review procedures to pursue the incorporation of their contributions in the final report.

The time available for return of government reviews should not be less than six weeks.

Preparation of a final draft report for submission to Working Group Plenary should be undertaken by lead authors, and Working Group co-chairs as appropriate. If necessary, and timing and funding permit, a wider meeting with principal contributors and reviewers is encouraged to pay special attention to particular points of assessment or areas of major differences. It is important that reports describe different (possibly controversial) scientific or technical views on a subject, particularly if they are relevant to the political debate. The final draft should credit all lead authors, contributors, expert reviewers, and country reviewers by name and affiliation.

## **Acceptance of the Report**

A final draft taking into account country comments should be distributed to all IPCC countries and participating organizations not less than three weeks prior to a Working Group Plenary meeting called to accept the report and transmit it to the IPCC Plenary. It is for the Working Group co-chairs to assess the time necessary for completing action in a timely manner, according to the complexity of the task and to the amount of work already in hand within the IPCC or other bodies already working in the field.

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## **Proposed Writing Teams and Assignments for the Working Group III Second Assessment Report**

The Working Group III Bureau has attempted to assign lead authors to writing teams by matching the author's expertise to the scope of the writing assignment. This is not an exact process, most authors have expertise related to several of the writing assignments and the Bureau's knowledge of each of the author's credentials is less than perfect.

The Bureau is open to transferring lead authors to writing teams which they feel better suit their qualifications. If you wish to transfer to another writing team, please contact Erik Haites, Head, Technical Support Unit, Working Group III at tel: +416-369-0900 or fax: +416-369-0922 as soon as possible. Your request will be addressed during the Lead Authors meeting in Seoul.

A convening Lead Author has been proposed by the Working Group III Bureau for each writing team. Each writing team will be asked to select/confirm a convening lead author during its meeting on September 7.

**PROPOSED WRITING ASSIGNMENTS FOR  
THE WORKING GROUP III  
SECOND ASSESSMENT REPORT  
(Draft, August 17, 1993)**

**PREFACE** Working Group III Bureau

The preface will outline the mandate and terms of reference of the working group, describe how it went about producing the report, what the intended audience of the report is, and the purposes for which the report should be used. The preface will note that none of the tasks shall involve the Working Group making policy judgements. Each chapter will also place the socioeconomic perspectives of climate change in the context of sustainable development. The working group should analyze the issues as broadly as possible recognizing the Rio Declaration on Environment and Development, Agenda 21 and in particular the Framework Convention on Climate Change, as adopted.

**EXECUTIVE SUMMARY** Working Group III Bureau for review by all lead authors

**SUMMARY FOR POLICY MAKERS** Working Group III Bureau for review by all lead authors

**PART I: SCOPE OF THE ASSESSMENT**

|                 |                                |
|-----------------|--------------------------------|
| Writing Team 1: | <b>SCOPE OF THE ASSESSMENT</b> |
| C               | *                              |
|                 | Jose Goldemberg, Brazil        |
|                 | Udo Simonis, Germany           |
|                 | *                              |
|                 | Joe Stiglitz, U.S.A.           |
|                 | *                              |
|                 | Akihiro Amano, Japan           |
|                 | *                              |
|                 | Xie Shaoxiong, China           |
|                 | *                              |
|                 | Ruby Saha, Mauritius           |

Part I will place global warming in a sustainable development context. This assessment will include, *inter alia*, the socio-economic perspectives of climate change, the nature of the interactions between economic activity and climate change, and emissions scenarios. The assessment will address the global nature

of the problem, taking into account particularly the circumstances of countries vulnerable to the impacts of climate change and to the impacts of response measures. In addition, it will cover a scientific evaluation of the appropriateness of the methodologies used for the analysis, including the socio-economic assumptions underlying existing modelling frameworks, its relations to observable data such as national accounts figures (GDP). To fulfil the scope of the analysis, existing supplementary indicators will be assessed.

Resource limitation that may affect global warming (eg. Fossil fuel reserves) or emission reduction options (eg. Hydro-electric potential, biomass fuel production) will be reviewed.

## **PART II: THE SOCIO-ECONOMICS OF IMPACTS, ADAPTATION, AND MITIGATION OF CLIMATE CHANGE**

The mandate of the Working Group states that it should undertake “Technical assessments of the socio-economics of impacts, adaptation and mitigation of climate change over both the short and long term and at the regional and global levels. The work plan should, *inter alia*, consider the following topics: top-down and bottom-up economic modelling . . . ; the evolution of technological change; methods for risk assessment; methods for the generic assessment of response instruments . . . .” For each theme in this part, a key question to be answered that addresses this section of the mandate has been identified.

### **CHAPTER 1: SOCIO-ECONOMIC FRAMEWORK FOR DECISION-MAKING**

**Note:** CHAPTER 1 is spread across THREE writing teams as indicated below.

Key question: How do we take socioeconomic factors into account when making decisions about the climate change issue? The issues addressed under this theme will include, *inter alia*:

#### **Writing Team 2: DECISION-MAKING FRAMEWORK**

- C    \*    Jyoti Parikh, India
- \*    Kenneth Arrow, U.S.A.
- \*    Gonzague Pillet, Switzerland
- ???, developing country
- ???, economy in transition

## Socio-economics of Climate Change in Relation to the Need for Sustainable Development

### Decision-making under uncertainty:

- The socio-economic factors to be considered when making decisions in the short and long term.
- Factoring the risks of increased frequency of extreme events and irreversibilities into decisions.

### Risk assessment including, *inter alia*, discussion of the following questions:

- What methods can be used to assess risk and what levels of confidence can be attached to such methods?
- What are the perceptions of and responses to risk?
- What are possible response measures?
- What are the risks of inaction and of undertaking “no-cost” or cost-effective “low-cost” response measures and of taking more far-reaching response measures? (This section should take into account sequential decision-making, portfolio analysis, benefits and costs of taking action early versus late, and the long-term implications of short-term decisions).

### The value of information including, *inter alia*, discussion of the following:

- Significant efforts are being undertaken every year on global climate research in the area of natural sciences. Where are the highest potential payoffs for likely future decisions? What are the most critical uncertainties, including scientific uncertainties? What kinds of research can reduce them and reinforce society’s ability to confront uncertainty? What is the value of this scientific research in terms of its ability to describe the linkages between the natural sciences and socio-economics? What are the predictable trends of scientific and technical progress in efficiency of use of different energy types with respect to carbon intensity and in the adaptation of species to new climatic situations?

**Writing Team 3:   APPLICABILITY OF BENEFIT-COST ANALYSIS  
TO CLIMATE CHANGE**

**C   \*   Mohan Munasinghe, World Bank  
          Michael Hoel, Norway  
          Carl-Christian von Weizsacker, Germany  
          ???, developing country  
          ???, Korea**

Can cost-benefit analysis be applied in a manner consistent with sustainable development?

Methods and applications of cost-benefit analysis including, *inter alia*:

- Concepts such as opportunity costs, trade-offs, marginal costs and marginal benefits, limitations of cost-benefit analysis and consideration of alternative methodologies, and the value and importance of non-market factors such as biodiversity, long-term discounting, public perceptions, social well-being, increased frequency of extreme events, thresholds, and irreversibilities.

**Writing Team 4:   EQUITY AND SOCIAL CONSIDERATIONS**

**C   \*   Harold Jacobson, U.S.A.  
          \*   Karl Goran-Maler, Sweden  
          Michael Grubb, U.K.  
          \*   Calestous Juma, Kenya  
          Tariq Banuri or Syed Qutub, Pakistan**

Equity considerations including, *inter alia*:

- Varying contributions between regions for past emissions, the “free rider” problem, inter-regional and inter-generational equity, and the question of the time lags between the incurring of costs and the accruing of benefits.

Sociological considerations.

Note: The assessment of these topics should establish the limits of scientific analysis and identify the role of values.

## CHAPTER 2: ASSESSING THE BENEFITS OF RESPONSES TO CLIMATE CHANGE

Key question: What methods exist for assessing the economic and social benefits of action and inaction? The issues addressed under this theme will include, *inter alia*:

### Writing Team 5: BENEFITS OF RESPONSES TO CLIMATE CHANGE

|   |   |                            |       |
|---|---|----------------------------|-------|
| C | * | David Pearce, U.K.         |       |
|   | * | Kerry Smith, U.S.A.        |       |
|   | * | William Cline, U.S.A.      |       |
|   | * | R.K. Pachauri, India       | WG II |
|   | * | Pier Vellinga, Netherlands | WG II |

Methods for estimating benefits:

- The status-quo option. What would be the socio-economic impacts in the absence of any action to deal with the problem of increasing concentrations in the atmosphere of greenhouse gases and aerosols? How would the benefits vary with different degrees and timing of actions to limit climate change?
- Methods based on market impacts. For example, adaptation through trade, market agents, migration of population, and economic activity.
- Methods based on non-market impacts such as ecological and social impacts.

Major issues in estimating benefits:

- An assessment of the state of knowledge related to issues involved in estimating benefits, including, *inter alia*, distinguishing between short-term and long-term impacts; the relationship of impacts to the degree, timing, and predictability of climate change; techniques for valuing impacts on ecosystems; hard-to-define values such as aesthetics, impacts on land use, impacts on biological diversity and other environmental problems and social well-being; and modelling limits dealing with thresholds, increased frequency of extreme events, irreversibilities, and time horizons.

Methods for estimating the costs of human adaptation.

### **CHAPTER 3: EVALUATING THE COSTS OF MITIGATION OF GREENHOUSE GAS EMISSIONS BY SOURCES AND REMOVAL BY SINKS**

**Note: CHAPTER 3 is spread across THREE writing teams as indicated below.**

Key question: What are economic, social, and environmental contributions to understanding, both conceptually and empirically, the costs of mitigation of greenhouse gas emissions? The issues addressed under this theme will include, *inter alia*:

|                        |          |                                                                                |
|------------------------|----------|--------------------------------------------------------------------------------|
| <b>Writing Team 6:</b> |          | <b>COSTS OF MITIGATION OF GREENHOUSE GAS<br/>EMISSIONS TO IN THE SHORT RUN</b> |
| <b>C</b>               | <b>*</b> | <b>John Robinson, Canada</b>                                                   |
|                        | <b>*</b> | <b>Olivier Godard, France</b>                                                  |
|                        | <b>*</b> | <b>Thomas Johansson, Sweden      WG II</b>                                     |
|                        |          | <b>Ogunlade Davidson, Sierra Leone</b>                                         |
|                        |          | <b>William Nordhaus, U.S.A.</b>                                                |
|                        | <b>*</b> | <b>Plino Nastari, Brazil</b>                                                   |

**Note: This team will focus on issue related to estimating costs of mitigation in the short run (roughly 10 to 25 years). In particular, it will focus on comparison of top-down and bottom-up modelling approaches and what can be learned from each.**

Variables for measuring costs.

- A discussion of costs from a long-term perspective, including, *inter alia*, measures such as social welfare, health and other environmental effects, real incomes, trade, productivity, and income transfers among regions.

Assumptions in empirical analysis including, *inter alia*:

- Modelling assumptions including uncertainties and ranges;
- Technological change;

- Macro-economic and demographic assumptions such as productivity growth, population and labour force change, and structural change in economies;
- Consumption patterns;
- Fuel supply schedules, including the potential of renewable fuel and energy technologies, demand and supply elasticities, and exchange rates; and
- Land use.

#### Modelling methods

- A description of various types of models (e.g., “top-down” and “bottom-up”) according to purpose, and a discussion of their relative strengths and weaknesses, including, *inter alia*, a discussion of data limitations and limitations of model applications, the reasons for differences in the predictions made by them and ways to evaluate those results, and the integration of modelling techniques (e.g., bottom-up studies of new technologies). The appropriateness of the modelling methods should be discussed in relation to the problems of developing countries and should reflect the concerns and special conditions of developing countries. The models should include as many different policy instruments as possible. Possible other issues include dynamic versus static models, econometric versus parametric models, perfect versus limited foresight in models, the treatment of international trade, model time horizons, and how various modelling techniques could be integrated. Different policy options will be used to derive model outputs.

#### Model comparisons

- A comparison of results including, *inter alia*, distributional impacts and reasons for differences, the impact of response measures by industrialized countries on developing countries, and a survey of the degree of dependency of countries on the production, exportation, and consumption of fossil fuel and associated energy-intensive products. A special effort will be made to incorporate developing country studies.

## from Chapter 2

### Major issues of cost estimation

- Potential topics include, *inter alia*, unilateral versus multilateral responses, with trading allowed or not; the timing of responses and the amounts of reductions; and other matters such as eliminating subsidies and recycling revenues.

### Topics for future work

- A discussion of the types of future research needed such as the integration of bottom-up studies into macroeconomic and general equilibrium models, research into the impacts of sustainable development practices, and identification of future work needs, particularly regarding the needs of developing countries.

### Writing Team 7: COSTS OF MITIGATION OF GREENHOUSE GAS EMISSIONS IN THE LONG RUN

- |   |   |                                  |
|---|---|----------------------------------|
| C | * | Jean-Charles Hourcade, France    |
|   |   | Andrew Dean or Peter Sturm, OECD |
|   | * | Richard Richels, U.S.A.          |
|   | * | Dale Jorgenson, U.S.A.           |
|   | * | Angelica Tudini, Italy           |
|   |   | ???, economy in transition       |
|   |   | ???, Korea                       |

**Note:** This team will focus on issue related to estimating cost of mitigation in the long-run (25 to 100 years or more). In particular it will focus on technological change, its impact on mitigation costs, and methods/costs of stimulating technological change.

**It will also deal with the question of the optimal trajectory to stabilization of atmospheric concentrations of greenhouse gases.**

### Variables for measuring costs.

- A discussion of costs from a long-term perspective, including, *inter alia*, measures such as social welfare, health and other environmental effects, real incomes, trade, productivity, and income transfers among regions.

Assumptions in empirical analysis including, *inter alia*:

- Modelling assumptions including uncertainties and ranges;
- Technological change;
- Macro-economic and demographic assumptions such as productivity growth, population and labour force change, and structural change in economies;
- Consumption patterns;
- Fuel supply schedules, including the potential of renewable fuel and energy technologies, demand and supply elasticities, and exchange rates; and
- Land use.

Model comparisons

- A comparison of results including, *inter alia*, distributional impacts and reasons for differences, the impact of response measures by industrialized countries on developing countries, and a survey of the degree of dependency of countries on the production, exportation, and consumption of fossil fuel and associated energy-intensive products. A special effort will be made to incorporate developing country studies.

from Chapter 2

Major issues of cost estimation

- Potential topics include, *inter alia*, unilateral versus multilateral responses, with trading allowed or not; the timing of responses and the amounts of reductions; and other matters such as eliminating subsidies and recycling revenues.

from Chapter 4

- Technological change. A discussion of the factors determining technological change as a driving force for, as well as a way to control net greenhouse gas emissions (e.g., renewable energy, low-energy systems, carbon sequestration, etc.), taking into

account the penetration, diffusion, and transfer of technology and the different dynamics in developed and developing countries; and which of these factors can be influenced and how.

#### Topics for future work

- A discussion of the types of future research needed such as the integration of bottom-up studies into macroeconomic and general equilibrium models, research into the impacts of sustainable development practices, and identification of future work needs, particularly regarding the needs of developing countries.

#### Writing Team 8: **POLICY INSTRUMENTS**

- |          |          |                                |
|----------|----------|--------------------------------|
| <b>C</b> | <b>*</b> | <b>Brian Fisher, Australia</b> |
|          |          | <b>Scott Barrett, U.K.</b>     |
|          | <b>*</b> | <b>Peter Bohm, Sweden</b>      |
|          | <b>*</b> | <b>Anwar Shah, World Bank</b>  |
|          |          | <b>Tomasz Zylicz, Poland</b>   |
|          | <b>*</b> | <b>J. Mubazi, Uganda</b>       |

Policy instruments for domestic and regional use including, *inter alia*:

- Economic instruments such as taxes, subsidies, tradeable permits, tradeable absorption obligations, user charges, and deposit-refund schemes;
- Regulatory instruments including technology-based and performance-based; and
- Other instruments such as land use programmes and public awareness and education programmes.

#### from Chapter 4

- Internationally coordinated instruments. A discussion of mechanisms such as “joint implementation,” carbon leakages (shifts of carbon-intensive activities) linked to demographics, consumption patterns, and economic growth of industrialized and developing countries, assistance and trade aspects, and the possibilities and difficulties of internationally coordinated instruments.

**Note** This team should also consider the issues related to structure of the carbon tax raised by Peter Read of New Zealand.

## **CHAPTER 4: GENERIC ASSESSMENT OF RESPONSE OPTIONS**

**Key question:** What methods exist for assessing the net costs and effectiveness of different response options in a comprehensive manner?

### **Writing Team 9: GENERIC ASSESSMENT OF RESPONSE OPTIONS**

**C \* Robert Stavins, U.S.A.**  
**\* R.S. Maya, Zimbabwe**  
**\* Catrinus Jepma, Netherlands**  
**Mohammed Asaduzzaman, Bangladesh**  
**\* Irving Mintzer, Stockholm Environment Institute**

The discussion of cost evaluation in each of these sections should incorporate a discussion of net costs and should include complementary socio-economic effects, both negative and positive, on such elements as GDP, employment levels, the balance of trade, economic structure, and the environment. The issues addressed under this theme will include, *inter alia*:

- **Adaptation options:** A discussion of different options for developed countries, developing countries, and those with special circumstances (e.g., low-lying, arid, and countries in transition).
- **Mitigation options:** A discussion of mitigation measures which should reflect, for example, the concept of comprehensiveness (all greenhouse gases, sinks, and sectors), including, *inter alia*, reducing emissions by correcting market and government policy shortcomings, eliminating subsidies and barriers, dissemination of information and technology cooperation, and introducing economic instruments.
- **Methods for assessing the effectiveness of options** including, *inter alia*, the use of models and the extent to which models incorporate the full range of options and conditions.
- **Comparison within and between mitigation and adaptation response options.** The comparison should include, *inter alia*, their cost-effectiveness, their influence on innovation and promoting

environmentally sound technologies, their influence on other environmental matters, their ease of administration, monitoring, and enforcement, their capacities to cope with uncertainties, their data requirements, and equity and sustainable development considerations.

## **PART III: EMISSIONS SCENARIOS**

### **CHAPTER 5: CONSIDERATIONS OF CONSISTENT SCENARIOS**

#### **Writing Team 10: EMISSIONS SCENARIOS**

|          |          |                                     |              |
|----------|----------|-------------------------------------|--------------|
| <b>C</b> | <b>*</b> | <b>Joseph Alcamo, Netherlands</b>   |              |
|          | <b>*</b> | <b>Tsuneyuki Morita, Japan</b>      |              |
|          | <b>*</b> | <b>Majid Al-Munif, Saudi Arabia</b> |              |
|          | <b>*</b> | <b>James (Jae) Edmonds, U.S.A.</b>  | <b>WG II</b> |
|          | <b>*</b> | <b>Zhou Dadi, China</b>             |              |
|          |          | <b>Amulya Reddy, India</b>          |              |
|          | <b>*</b> | <b>Aca Sugandhy, Indonesia</b>      |              |

The mandate of the Working Group states that it “should consider . . . a range of internally consistent scenarios for future emissions based on reasonable economic, demographic and technological projections.” With this in mind, the key question to be answered is, “Which issues and uncertainties about key variables may critically affect future net greenhouse gas emissions and aerosol concentrations?” The issues addressed under this theme will include, *inter alia*:

- Types of models for scenario development and their application.
- The assumptions made in developing existing scenarios. A discussion of the key assumptions concerning, *inter alia*, economic growth, demographics, consumption patterns, technological change, energy prices and supply, international trade flows, distributional issues, social change, sustainable development, land use, and non-greenhouse gas environmental constraints such as acid rain.
- The relative importance and sensitivity of different variables in determining future emissions and sinks.
- The relationships among key variables.
- The sensitivity of these variables, most notably to government actions.

- The relationship of scenarios to the emissions inventory methodology developed by Working Group I. A number of country studies are being completed and could make a useful contribution to scenario analysis.
- The degree of uncertainty, including, *inter alia*, a discussion of the following questions:
  - What are the gaps and uncertainties in available knowledge about these factors and their influences on emissions?
  - What does the extent of this uncertainty tell us about the validity of current scenarios? How do existing IPCC scenarios compare with other existing scenarios? Are new scenarios required?
  - What are likely to be the impacts of this uncertainty on short- and long-term future emission scenarios?
- Model structures for analysis of scenarios, including, *inter alia*, a discussion of the following questions:
  - How useful are current models in terms of their regional detail, solution algorithms, and data?
  - What are the characteristics of current models?
  - What is the sensitivity and flexibility of models to technical and structural assumptions?
- The appropriate uses, capabilities, and limitations of emissions scenarios in scientific assessment and policy-making.
- An assessment of the need for future work on scenarios to serve the needs of climate modelling, planning of response measures, and provision of information to the Conference of Parties to the Framework Convention on Climate Change.

## Schedule for the Work of Working Group III

Revised July 30, 1993

|                                       |                                                                                                                                                   |
|---------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| Aug. 15, 1993                         | Final submissions of lead author nominees and final adjustments to writing teams for WG III.                                                      |
| Aug. 16, 1993                         | WG III Bureau finalizes the list of lead authors.                                                                                                 |
| Aug. 30 to<br>Sept. 3, 1993<br>Geneva | WG III representatives attend WG II lead authors meeting.                                                                                         |
| Sept. 6-8, 1993<br>Seoul              | WG III lead authors meeting.                                                                                                                      |
| <i>Sept. 1993 to<br/>Feb. 1994</i>    | <i>Lead authors for review of current emissions scenarios prepare first draft of their chapter.</i>                                               |
| Sept. 1993 to<br>Aug. 1994            | Workshops are held and lead authors prepare first drafts of Second Assessment Report (SAR) chapters.                                              |
| Dec. 6-8, 1993<br>Shepperton, U.K.    | WG III bureau participates in proposed WG I Bureau meeting to review progress of collaborative efforts.                                           |
| <i>Feb. 3, 1994<br/>Geneva</i>        | <i>Expanded WG III Bureau meeting to review evaluation of current emissions scenarios.</i>                                                        |
| Feb. 4-5, 1994<br>Geneva              | IPCC Bureau meets to review collaborative mechanisms and to monitor progress of IPCC work.                                                        |
| <i>Mar. 1, 1994</i>                   | <i>Draft evaluation of current emissions scenarios completed and distributed for peer review.</i>                                                 |
| <i>Mar. 31, 1994</i>                  | <i>Peer review comments on draft evaluation of current emissions scenarios received. Experts prepare the first draft of material for the COP.</i> |

Note: Items in italics relate to the review of emissions scenarios. Joint meetings of the Working Group II and Working Group III Bureaus will be scheduled at appropriate times.

|                                         |                                                                                                                                                                                                |
|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>April 1994<br/>Fortaleza, Brazil</i> | <i>Expanded WG III Bureau meeting to review draft material for the COP. Workshop on emissions scenarios.</i>                                                                                   |
| April 11-15, 1994<br>Fortaleza, Brazil  | WG III participates in proposed joint workshop with WG I and WG II on stabilization of atmospheric concentrations, regional climate change scenarios and implications for impacts assessments. |
| <i>May 1994</i>                         | <i>Draft evaluation of current emissions scenarios for COP circulated for review by countries and organizations.</i>                                                                           |
| <i>July 1994</i>                        | <i>Draft evaluation of current emissions scenarios for COP revised in light of government comments.</i>                                                                                        |
| Aug. 31, 1994                           | Drafts of chapters for the SAR sent to the WG III Bureau by writing teams for preparation by Bureau of Executive Summary and Policy Makers Summary.                                            |
| <i>Sept. 5, 1994<br/>Geneva</i>         | <i>WG III Bureau Meeting to approve emission scenario report for COP.</i>                                                                                                                      |
| <i>Sept. 6-7, 1994<br/>Geneva</i>       | <i>WG III Plenary to approve emission scenario report for COP.</i>                                                                                                                             |
| Sept. 8-10, 1994<br>Geneva              | Lead authors meeting to discuss draft chapters, overlaps, and key points for summaries.                                                                                                        |
| Oct. 1994                               | Co-chairs distribute first draft of SAR chapters, draft Executive Summary and Policy Makers Summary for peer review.                                                                           |
| <i>Nov. 10 -12, 1994<br/>Nairobi</i>    | <i>IPCC Plenary approves evaluation of current emissions scenarios for COP.</i>                                                                                                                |
| Dec. 1994 to<br>Feb. 1995               | Lead authors and WG III Bureau revise SAR based on peer review comments.                                                                                                                       |
| Jan. 1995                               | Workshop on Article 2 of the Framework Convention on Climate Change.                                                                                                                           |
| End Feb. 1995                           | Revised draft of SAR circulated for review by countries and organizations.                                                                                                                     |

Note: Items in italics relate to the review of emissions scenarios. Joint meetings of the Working Group II and Working Group III Bureaus will be scheduled at appropriate times.

|                   |                                                                                                                                                                              |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Apr. to May, 1995 | Lead authors and WG III Bureau prepare final draft of SAR including the Executive Summary and Policy Makers Summary based on comments from IPCC countries and organizations. |
| May 1995          | WG III Bureau meets to approve SAR chapters, Executive Summary and Policy Makers Summary.                                                                                    |
| June 1995         | WG III Plenary considers SAR chapters and approves Executive Summary and Policy Makers Summary.                                                                              |
| Sept. 1995        | IPCC Plenary adopts SAR.                                                                                                                                                     |
| Oct. 1995         | SAR printed and distributed.                                                                                                                                                 |

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Note: Items in italics relate to the review of emissions scenarios. Joint meetings of the Working Group II and Working Group III Bureaus will be scheduled at appropriate times.

# **Schedule for the Work of Working Group III**

Revised July 30, 1993

|                                       |                                                                                                                                                                                                |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sept. 1993 to<br>Aug. 1994            | Workshops are held and lead authors prepare first drafts of Second Assessment Report (SAR) chapters.                                                                                           |
| Dec. 6-8, 1993<br>Shepperton,U.K.     | WG III bureau participates in proposed WG I Bureau meeting to review progress of collaborative efforts.                                                                                        |
| Feb. 4-5, 1994<br>Geneva              | IPCC Bureau meets to review collaborative mechanisms and to monitor progress of IPCC work.                                                                                                     |
| April 11-15,1994<br>Fortaleza, Brazil | WG III participates in proposed joint workshop with WG I and WG II on stabilization of atmospheric concentrations, regional climate change scenarios and implications for impacts assessments. |
| Aug. 31, 1994                         | Drafts of chapters for the SAR sent to the WG III Bureau by writing teams for preparation by Bureau of Executive Summary and Policy Makers Summary.                                            |
| Sept. 8-10, 1994<br>Geneva            | Lead authors meeting to discuss draft chapters, overlaps, and key points for summaries.                                                                                                        |
| Oct. 1994                             | Co-chairs distribute first draft of SAR chapters, draft Executive Summary and Policy Makers Summary for peer review.                                                                           |
| Dec. 1994 to<br>Feb. 1995             | Lead authors and WG III Bureau revise SAR based on peer review comments.                                                                                                                       |
| Jan. 1995                             | Workshop on Article 2 of the Framework Convention on Climate Change.                                                                                                                           |
| End Feb. 1995                         | Revised draft of SAR circulated for review by countries and organizations.                                                                                                                     |
| Apr. to May, 1995                     | Lead authors and WG III Bureau prepare final draft of SAR including the Executive Summary and Policy Makers Summary based on comments from IPCC countries and organizations.                   |

|            |                                                                                                 |
|------------|-------------------------------------------------------------------------------------------------|
| May 1995   | WG III Bureau meets to approve SAR chapters, Executive Summary and Policy Makers Summary.       |
| June 1995  | WG III Plenary considers SAR chapters and approves Executive Summary and Policy Makers Summary. |
| Sept. 1995 | IPCC Plenary adopts SAR.                                                                        |
| Oct. 1995  | SAR printed and distributed.                                                                    |

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# **List of Workshops ~**

## **WORKING GROUP III WORKSHOPS**

**January 17-20, 1994  
Japan**

### **Policy Instruments and their Implications**

Japan has expressed interest in organizing a workshop for WG III January 17 - 20, 1994. They will be asked to consider a workshop on policy instruments and their implications.

**Late March/Early April 1994  
Switzerland**

### **Decision-making framework**

**Mid-April, 1994  
Brazil**

### **Greenhouse Gas Emissions Scenarios**

A workshop on the review of current emissions scenarios will be held in Fortaleza, Brazil in April, 1994.

**July, 1994  
Kenya**

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

This workshop will be held in Mombassa, Kenya in July 1994. The writing team addressing equity and social issues will be asked to provide suggestions for the agenda that will help them with their work.

**October 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. It will be asked to host this workshop in October, 1994.

**Summer 1994**

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

## **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.

**Mid-April, 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. WG I is organizing this workshop which will be held in Fortaleza, Brazil in mid-April, 1994.

**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**

**October 13-15, 1993  
Laxenburg, Austria**

**IIASA workshop on the interrelationships between  
adaptation and mitigation measures.**

Dr. Haites will attend on behalf of WG III.

**October 20-22, 1993  
Cambridge, Massachusetts**

**MIT Global Change Forum V**

The forum will review progress in integrating climate and energy/economic models and discuss next steps in integrated assessment.

Dr. Haites will participate on behalf of WG III.

**November 8-10, 1993  
Lisbon, Portugal**

**IPIECA Seminar on Socio-Economic Aspects of Global  
Climate Change.**

**December 6-10, 1993  
Perth, Australia**

**Modelling Change in Environment and Socio-economic  
Systems.**

Sponsored by International Environmetrics Society,  
International Society for Ecological Modelling et al.,  
University of Western Australia

Contact: Tony Jakeman, 61 6 249 4742

**December 13-15, 1993  
Maastricht, Netherlands**

**Non-CO<sub>2</sub> Greenhouse Gases: Why and How to Control?**

International Symposium organized by the Society for Clean Air in the Netherlands. The European Symposium on Environmental Protection.

Contact: Vereniging LUCHT, 31 15 696884

**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.

## **Issues and Parameters Common to Multiple Writing Teams**

The IPCC has adopted sustainable development as the criterion for decisions related to climate change. Can we specify an operational definition of sustainable development in this context? Is stabilization of atmospheric concentrations at current levels a reasonable definition?

Can the benefits of avoiding climate change be estimated in a manner consistent with the definition of sustainable development and with sufficient accuracy to apply benefit-cost analysis?

What is an appropriate (range for the) social discount rate applied to climate change?

What is an appropriate decision making framework for dealing with climate change given the scientific uncertainties, the long time horizon, and the potential for irreversible environmental changes?

What approaches can be used to establish guidelines for inter regional and intergenerational equity and resource transfers from developed to developing countries?

Can we distinguish the costs of achieving a greenhouse gas emissions target from the cost of the policies used to achieve the target?

Can limits be defined for the contributions of different technologies, such as energy-efficiency, nuclear, and biomass, to limiting greenhouse gas emissions?

Is it useful to establish an optimal trajectory of greenhouse gas emissions targets?

What are the costs of unilateral action to limit greenhouse gas emissions? Can action by a few countries reduce costs for those countries? Can such a group be structured to make participation by non-participants attractive to everyone?

Do emissions scenarios depend more on the model or the key input assumptions?

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## **Travel Arrangements**

Please make your own flight arrangements.

The lead authors meeting will be held at the Sheraton Walker Hill Hotel in the eastern part of Seoul. A special rate of U.S. \$143 per night, including VAT and service charge has been negotiated. The hotel address, telephone and fax numbers are as follows:

Sheraton Walker Hill Hotel and Towers  
San 21, Kwangjang-Dong, Sungdong-Ku  
Korea 133-210  
Tel: 82 2 453 0121/0131  
Fax: 82 2 452 6867

**PLEASE MAKE YOUR HOTEL RESERVATIONS THROUGH DR. JOO HEON PARK  
AT THE KOREA ENERGY ECONOMICS INSTITUTE; TEL +82 343 20 2271, FAX +82  
343 21 0688.**

The hotel is approximately 90 minutes from Kimpo International Airport by bus. A KAL limousine bus runs from the airport to the hotel with departures every 30 minutes. The bus fare is 3,500 Won.

## **Travel Documents**

**YOU MAY NEED A VISA.** Please check with your travel agent or Korean embassy/consulate/travel office to determine whether you need a visa.

If you need a visa, you will need to provide three Korean references. You can use the following references:

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**C. WORKPLAN OF THE IPCC  
REORGANIZED WORKING GROUP III**

Explanatory Notes

**Scope of Work**

The efforts of the newly reconstituted Working Group III of IPCC will be carried out in the manner described in this work plan. Attached, and forming part of the work plan are the outline of the themes to be considered in the Working Group III Second Assessment Report (SAR) (Annex D) and the time-line for completion of various phases of the work (Annex G).

The Working Group will, in accordance with its Terms of Reference (see Annex C), prepare a comprehensive technical assessment of the socio-economics of mitigation of climate change, the impacts of climate change and adaptation to climate change over both the short and long term and at the regional and global levels. This contrasts with the work of Working Group II, which will be assessing the economic impacts on particular economic sectors at a more local level. Nevertheless, considerable collaboration between the two working groups will be necessary.

As reflected in United Nations General Assembly document A/AC.237/30 the chair of the Intergovernmental Negotiating Committee (INC) for the Framework Convention on Climate Change has requested that IPCC prepare, in time for the first meeting of the Conference of the Parties to the Convention (COP), "an evaluation of current scenarios of greenhouse gas<sup>1</sup> emissions and removals by sinks". The proposed time line addresses this request and assumes that the first meeting of the COP will take place in the spring of 1995. If this turns out not to be the case, the timing of activities shown that relate to the evaluation of scenarios would be adjusted accordingly. This element of the work is expected to build heavily on the work of the 1992 IPCC Update, which contained six greenhouse gas emissions scenarios. It is suggested that this work be carried out by examining the major assumptions made in developing the original scenarios and, based on whatever new information is available, assessing the validity and appropriateness of those assumptions and making recommendations on the need for updated or new scenarios. If it is agreed that new scenarios are needed, actions will have to be taken to develop them for the Second Assessment Report. The work on responding to the INC request will be closely co-ordinated with that on the same issue for the SAR by involving the same group of contributors. The IPCC Bureau is seeking clarification of the other elements of the INC's request, which raise cross-cutting issues which Working Group III may need to consider.

In evaluating scenarios and in developing its scientific and technical assessment, the Working Group proposes to undertake a number of specific activities, which are described in this work plan.

**Principal Considerations**

The work of the Working Group will be carried out with the following considerations in mind:

- a) It will place the socio-economic perspectives of climate change in the context of sustainable development. In particular, and in accordance with the Framework Convention on Climate Change, the work of the Working Group will be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation and comprise all economic sectors.
- b) Institution and endogenous capacity building in developing countries will be integrated into the work programme.
- c) The work of the Working Group will not stand in isolation from other IPCC

<sup>1</sup>Throughout this document, the term "greenhouse gas" is as defined in Article 1 of the Framework Convention on Climate Change

activities. Consultation and co-ordination with the activities of the other Working Groups will be carried out to the greatest extent possible.

- d) The work will, to the greatest extent possible, build on existing work, recognizing that the IPCC role is one of assessing existing knowledge for the Second Assessment Report.
- e) The activities of the Working Group will take into account the special situations of developing countries and economies in transition and will be carried out at a pace and be of a type that allows for the full involvement of these countries.
- f) The work will be carried out in as cost-efficient a manner as possible, bearing in mind the limited resource capacity of IPCC and all member countries. This implies close co-operation with other bodies working in the same fields in order to avoid duplication of effort.

Activities of  
the Working  
Group

The Working Group will prepare a report comprising its contribution to the IPCC Second Assessment Report and containing a technical assessment of the state of knowledge of the socio-economics of climate change mitigation, adaptation and impacts, taking into account the factors described in part (a) of the Terms of Reference of the Working Group. It is proposed that the structure of this report follow the proposed outline of the themes shown in Annex D.

The Working Group will also prepare a report, in time for the first meeting of the Conference of the Parties to the Convention, on the validity, appropriateness and utility of existing net greenhouse gas emissions scenarios based on the factors described in part (b) of the Terms of Reference of the Working Group. An update of this report, including any new scenarios that it is agreed should be developed, will be included in the Group's contribution to the IPCC SAR.

The preparation of both reports would be carried out as follows, using the dates indicated in the time line in accordance with the procedures described in the IPCC proposal for procedures for preparation, review and adoption of IPCC reports:

- The Bureau of the Working Group will ask governments and participating organizations to identify experts in their countries who could be involved as part of teams of lead authors, contributors, and expert reviewers for each report. Governments will also be asked to identify IPCC contacts for the purpose of co-ordinating later review by their governments.
- The Bureau of the Working Group will ask governments to suggest themes, dates and locations for IPCC workshops that could be held to review the scenarios and the scientific and technical work that is being assessed, bearing in mind the principal considerations noted above and the IPCC workshop policy. For reasons of economy and to avoid overlap and duplication, the Bureau will co-ordinate with other IPCC Working Groups and international organizations in conducting these workshops.
- Based on the suggestions of governments and participating organizations, the Bureau will meet with the Chair of IPCC and possibly with some of the experts identified, to decide on the detailed contents of each section of the reports, assign teams of lead authors for each section, and decide on which workshops should be held. The Bureau will also decide, from the perspective of Working Group III, whether IPCC co-sponsorship should be extended to other workshops, seminars or meetings.
- Lead authors will undertake preparation of the first drafts of each section and submit them to the Co-chairs, bearing in mind the tasks and responsibilities identified for contributors and themselves.

- The first drafts will be circulated for peer review to the specialists. Referenced material will be made available by the Co-chairs, who will collect the comments of the reviewers and make them available to the lead authors. Lead authors will then revise the drafts and if time permits in the schedule indicated in the time line, Co-chairs will circulate the revised drafts again for review.
- The revised drafts will be sent to governments and participating organizations for review.
- The summary for policy makers will be approved at a meeting of the Working Group in Plenary session and adopted by the Panel.

TERMS OF REFERENCE OF IPCC WORKING GROUP III

Working Group III should deal with cross-cutting economic and other issues related to climate change. Two issues have been identified below at this stage. The IPCC may add other issues at subsequent plenary sessions. The Working Group shall establish its work plan for tasks (a) and (b) below, which shall be available to the IPCC for subsequent review as its work proceeds.

- (a) Technical assessments of the socio-economics of impacts, adaptation and mitigation of climate change over both the short and long term and at the regional and global levels. The work plan should, inter alia, consider the following topics: top-down and bottom up economic modelling while taking into account assumptions, variables and applicability to and in different national economic circumstances; the evolution of technological change; methods for risk assessment; methods for the generic assessment of response instruments provided, however, that none of these tasks shall involve the Working Group in making policy judgements.
- (b) The Working Group should consider and develop as necessary a range of internally consistent scenarios for future emissions based on reasonable economic, demographic and technological projections, and taking account of gaps and uncertainties in available knowledge, especially concerning the evolution of socio-economic development and technology; where possible, policy assumptions should reflect their economic and social consequences. The scenarios are intended to assist Working Groups I and II in their assessment of a range of future changes of atmospheric composition, resulting climate changes, and their impacts.

This work should be carried out in consultation with Working Groups I and II.

A peer review process should be incorporated in the preparation of the reports of the Working Group.

## OUTLINE OF THE THEMES TO BE CONSIDERED IN THE WORKING GROUP III SECOND ASSESSMENT REPORT

### PREFACE

The preface will outline the mandate and terms of reference of the working group, describe how it went about producing the report, what the intended audience of the report is and the purposes for which the report should be used. The preface will note that none of the tasks shall involve the Working Group making policy judgements. Each chapter will also place the socio-economic perspectives of climate change in the context of sustainable development. The working group should analyze the issues as broadly as possible recognizing the Rio Declaration on Environment and Development, Agenda 21 and in particular the Framework Convention on Climate Change, as adopted.

### EXECUTIVE SUMMARY

#### SUMMARY FOR POLICY-MAKERS

#### THE SECOND ASSESSMENT REPORT

The SAR consists of three parts. The first part addresses the scope of the assessment, and the remaining two parts address the mandate of the Working Group.

#### **PART I: SCOPE OF THE ASSESSMENT**

This assessment will include, inter alia, the socio-economic perspectives of climate change, the nature of the interactions between economic activity and climate change, and emissions scenarios. The assessment will address the global nature of the problem, taking into account particularly the circumstances of countries vulnerable to the impacts of climate change and to the impacts of response measures. In addition, it will cover a scientific evaluation of the appropriateness of the methodologies used for the analysis, including the socio-economic assumptions underlying existing modelling frameworks, its relations to observable data such as national accounts figures (GDP). To fulfil the scope of the analysis, existing supplementary indicators will be assessed.

#### **PART II: THE SOCIO-ECONOMICS OF IMPACTS, ADAPTATION AND MITIGATION OF CLIMATE CHANGE**

The mandate of the Working Group states that it should undertake "Technical assessments of the socio-economics of impacts, adaptation and mitigation of climate change over both the short and long term and at the regional and global levels. The work plan should, inter alia, consider the following topics: top-down and bottom up economic modelling...; the evolution of technological change; methods for risk assessment; methods for the generic assessment of response instruments...". For each theme in this part, a key question to be answered that addresses this section of the mandate has been identified.

#### **CHAPTER 1: SOCIO-ECONOMIC FRAMEWORK FOR DECISION-MAKING**

Key Question: How do we take socio-economic factors into account when making decisions about the climate change issue? The issues addressed under this theme will include, inter alia:

Socio-economics of climate change in relation to the need for sustainable development

### Decision-making under uncertainty

The socio-economic factors to be considered when making decisions in the short and long term.

### Risk assessment including, inter alia, discussion of the following questions:

What methods can be used to assess risk and what levels of confidence can be attached to such methods?  
What are the perceptions of and responses to risk?  
What are possible response measures?  
What are the risks of inaction and of undertaking "no-cost" or cost effective "low-cost" response measures and of taking more far reaching response measures? (This section should take into account sequential decision-making, portfolio analysis, benefits and costs of taking action early versus late, and the long-term implications of short-term decisions).

### Equity considerations including, inter alia:

Varying contributions between regions for past emissions, the "free rider" problem, efficiency and consumption patterns, inter-regional and inter-generational equity and the question of the time lags between the incurring of costs, the accruing of benefits and/or disbenefits.

### Methods and applications of cost-benefit analysis including, inter alia:

Concepts such as opportunity costs, trade-offs, marginal costs and marginal benefits, limitations of cost-benefit analysis and consideration of alternative methodologies, and the value and importance of non-market factors such as biodiversity, long-term discounting, public perceptions, social well-being, thresholds and irreversibilities.

### The value of information including, inter alia, discussion of the following:

Significant efforts are being undertaken every year on global climate research in the area of natural sciences. Where are the highest potential payoffs for likely future decisions? What are the most critical uncertainties, including scientific uncertainties? What kinds of research can reduce them and reinforce society's ability to confront uncertainty? What is the value of this scientific research in terms of its ability to describe the linkages between the natural sciences and socio-economics? What are the predictable trends of scientific and technical progress in efficiency of use of different energy types with respect to carbon intensity and in the adaptation of species to new climatic situations?

### Sociological considerations

## **CHAPTER 2: ASSESSING THE BENEFITS OF RESPONSES TO CLIMATE CHANGE**

Key Question: What methods exist for assessing the economic and social benefits of action and inaction? The issues addressed under this theme will include, inter alia:

### Methods for estimating benefits

The status-quo option. What would be the socio-economic impacts in the absence of any action to deal with the problem of increasing concentrations in the atmosphere of greenhouse gases and aerosols? How would the benefits vary with different degrees and timing of actions to limit climate change?

Methods based on market impacts - for example, adaptation through trade, market agents, migration of population and economic activity.

Methods based on non-market impacts such as ecological and social impacts.

### Major issues in estimating benefits

An assessment of the state of knowledge related to issues involved in estimating benefits, including, inter alia, distinguishing between short-term and long-term impacts; the relationship of impacts to the degree, timing and predictability of climate change; techniques for valuing impacts on ecosystems; hard-to-define values such as aesthetics, impacts on land use, impacts on biological diversity and other environmental problems, social well-being; and modelling limits dealing with thresholds, irreversibilities and time horizons.

### Methods for estimating the costs of human adaptation

## **CHAPTER 3: EVALUATING THE COSTS OF MITIGATION OF GREENHOUSE GAS EMISSIONS BY SOURCES AND REMOVAL BY SINKS**

Key question: What are economic, social and environmental contributions to understanding, both conceptually and empirically, the costs of mitigation of greenhouse gas emissions? The issues addressed under this theme will include, inter alia:

### Variables for measuring costs

A discussion of costs from a long-term perspective, including, inter alia, measures such as social welfare, health and other environmental effects, real incomes, trade, productivity, and income transfers among regions.

### Assumptions in empirical analysis including, inter alia:

- Modelling assumptions including uncertainties and ranges
- Technological change
- Macro-economic and demographic assumptions such as productivity growth, population and labour force change and structural change in economies
- Consumption patterns
- Fuel supply schedules, including the potential of renewable fuel and energy technologies, demand and supply elasticities and exchange rates
- Land use

### Policy instruments, and their potential effects, for domestic and regional use including, inter alia:

- Economic instruments such as taxes, subsidies, tradeable permits, tradeable absorption obligations, user charges and deposit-refund schemes
- Regulatory instruments including technology-based and performance-based
- Other instruments such as land use programmes and public awareness and education programmes

### Modelling Methods

A description of various types of models (eg. "top down" and "bottom up") according to purpose, and a discussion of their relative strengths and weaknesses, including, inter alia, a discussion of data limitations and limitations of model applications, the reasons for differences in the predictions made by them and ways to evaluate those results, and the integration of modelling techniques (eg. bottom up studies of new technologies). The appropriateness of the modelling methods should be discussed in relation to the problems of developing countries and should reflect the concerns and special conditions of developing countries. The models should include as many different policy instruments as possible. Possible other issues include dynamic versus static models, econometric

versus parametric models, perfect versus limited foresight in models, the treatment of international trade, model time horizons and how various modelling techniques could be integrated. Different policy options will be used to derive model outputs.

#### Model Comparisons

A comparison of results including, inter alia, distributional impacts and reasons for differences, the impact of response measures by industrialized countries on developing countries and a survey of the degree of dependency of countries on the production, exportation and consumption of fossil fuel and associated energy-intensive products. A special effort will be made to incorporate developing country studies.

#### Major issues of cost estimation

Potential topics include, inter alia, unilateral versus multilateral responses, with trading allowed or not; the timing of responses and the amounts of reductions; and other matters such as eliminating subsidies and recycling revenues.

#### Topics for future work

A discussion of the types of future research needed such as the integration of bottom up studies into macroeconomic and general equilibrium models, research into the impacts of sustainable development practices, and identification of future work needs, particularly regarding the needs of developing countries.

### **CHAPTER 4: GENERIC ASSESSMENT OF RESPONSE OPTIONS**

Key question: What methods exist for assessing the net costs and effectiveness of different response options in a comprehensive manner?

The discussion of cost evaluation in each of these sections should incorporate a discussion of net costs and should include complementary socio-economic effects, both negative and positive, on such elements as GDP, employment levels, the balance of trade, economic structure, and the environment. The issues addressed under this theme will include, inter alia:

#### Adaptation options

A discussion of different options for developed countries, developing countries and those with special circumstances (e.g. low lying, arid, and countries in transition).

#### Mitigation options

A discussion of mitigation measures which should reflect, for example, the concept of comprehensiveness (all greenhouse gases and sinks and sectors), including, inter alia, reducing emissions by correcting market and government policy shortcomings, eliminating subsidies and barriers, dissemination of information and technology co-operation, and introducing economic instruments.

#### Methods for assessing the effectiveness of options including, inter alia, the use of models and the extent to which models incorporate the full range of options and conditions

#### Comparison within and between mitigation and adaptation response options

The comparison should include, inter alia, their cost effectiveness, their influence on innovation and promoting environmentally sound technologies, their influence on other environmental matters, their ease of administration monitoring and enforcement, their capacities to cope with uncertainties, their data requirements and equity and sustainable development considerations.

### Technological change

A discussion of the factors determining technological change as a driving force for, as well as a way to control net greenhouse gas emissions (e.g. renewable energy, low energy systems, carbon sequestration, etc.), taking into account the penetration, diffusion and transfer of technology and the different dynamics in developed and developing countries; and which of these factors can be influenced and how.

### Internationally-coordinated instruments

A discussion of mechanisms such as "joint implementation", carbon leakages (shifts of carbon-intensive activities) linked to demographics, consumption patterns and economic growth of industrialized and developing countries, assistance and trade aspects, and the possibilities and difficulties of internationally co-ordinated instruments.

## **PART III: EMISSIONS SCENARIOS**

### **CHAPTER 5: CONSIDERATIONS OF CONSISTENT SCENARIOS**

The mandate of the Working Group states that it "should consider...a range of internally consistent scenarios for future emissions based on reasonable economic, demographic and technological projections." With this in mind, the key question to be answered is "Which issues and uncertainties about key variables may critically affect future net greenhouse gas emissions and aerosol concentrations?"--The issues addressed under this theme will include, inter alia:

#### Types of models for scenario development and their application

#### The assumptions made in developing existing scenarios

A discussion of the key assumptions concerning, inter alia, economic growth, demographics, consumption patterns, technological change, energy prices and supply, international trade flows, distributional issues, social change, sustainable development, land use, and non-greenhouse gas environmental constraints such as acid rain.

#### The relative importance and sensitivity of different variables in determining future emissions and sinks

#### The relationships among key variables

#### The sensitivity of these variables, most notably to government actions

#### The relationship of scenarios to the emissions inventory methodology developed by Working Group I

- A number of country studies are being completed and could make a useful contribution to scenario analysis

#### The degree of uncertainty including, inter alia, a discussion of the following questions:

- What are the gaps and uncertainties in available knowledge about these factors and their influences on emissions?
- What does the extent of this uncertainty tell us about the validity of current scenarios? How do existing IPCC scenarios compare with other existing scenarios? Are new scenarios required?
- What are likely to be the impacts of this uncertainty on short and long-term future emission scenarios?

Model structures for analysis of scenarios including, inter alia, a discussion of the following questions:

- How useful are current models in terms of their regional detail, solution algorithms and data?
- What are the characteristics of current models?
- The sensitivity and flexibility of models to technical and structural assumptions

The appropriate uses, capabilities, and limitations of emissions scenarios in scientific assessment and policy-making

An assessment of the need for future work on scenarios to serve the needs of climate modelling, planning of response measures, and provision of information to the Conference of Parties to the Framework Convention on Climate Change

Please Deliver Immediately!

Faxed Comments from:

Schwalbe

Amano

Reilly

Bruce



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August 24, 1994

Dr. Joseph Stiglitz  
Dr. Sally Kane  
Council of Economic Advisers  
Old Executive Office Building  
Room 315  
Washington, DC 20500

Fax: 395-6853

Dear Joe and Sally:

Thanks for sending me the draft of the IPCC "Scope" chapter. I have made marginal notes on the pages enclosed.

I think it is a nice overall review. Your task is complicated by the problem that you risk repeating virtually everything the rest of the study addresses. You asked what I thought should be kept in a drastic slimming-down (I believe, Sally, you said only 15 pages could be kept).

Perhaps three criteria are relevant for paring. First, what sections can go because they are most directly duplicative of what is in the other chapters. Second, what sections should be kept because they set out the conceptual framework that is the tip of the iceberg for the material that follows in the other chapters. Third, what sections should be kept simply because they are unusually good, even though there may be some risk of repetition elsewhere.

On the basis of these three criteria, here are the sections that make my first cut and are good candidates for retention (albeit probably with editing to downsize):

1.3.3  
1.3.4  
1.4.1.1 through 1.4.2.1  
1.4.3  
1.4.6.1 (but with substantive improvements)  
1.5.2 through 1.5.4  
1.7.1 through 1.7.4  
1.8.1

Dr. Joseph Stiglitz  
Dr. Sally Kane  
August 24, 1994  
Page Two

As for my own area, I found most of the points in the section on damages from global warming are already covered in the chapter from my writing team. There are some disagreements on some specifics, in particular the tone of whether agricultural damage is major or not and the diagnosis of net space-climatization effects. I did not include the Gruenspecht piece because it was not yet in the public domain; as you will see in the draft damages chapter, I think there is other evidence to the contrary. Perhaps some of your points on these divergences should be kept in your section. Also, I was sorry to see your section on damages seemed to ignore the longer-term warming beyond  $2xCO_2$ . I thought by now this was becoming part of the conventional wisdom. It is addressed substantially in my writing team's chapter, but a more explicit cross reference would seem appropriate. The problem, and the calculus, are simply radically different if there is truncation at  $2xCO_2$ .

I think the discussion of discounting should remain, because this is so central that it is a strength rather than a weakness to have it come up again in the cost-benefit chapter and in the damages chapter. This document is not by faceless bureaucrats; readers know the names of the chapter authors and have a right to expect the unique insights of the different authors.

One aspect that concerned me was that at places the chapter seemed to come over as a lecture by industrial country economists on how the LDCs weren't doing their part. I would prefer that the attack on the Rio convention be rephrased along the following lines. Everyone knows that sooner or later the LDCs will have to be brought into the process of emissions limits. However, this is very much a staged international policy response with a large element of contingent action in response to additional scientific information. In a first stage, there are good grounds for having the countries most able to afford restricting emissions take the lead. Even in this stage, they can often do so most efficiently by projects in LDCs (joint implementation). Then in a second stage (after 2000 and, probably, scientific firming up, for example from earth-satellite observations on cloud properties scheduled for the late 1990s), more generalized efforts including the LDCs would probably be necessary.

You should be forewarned that the LDCs will violently react to the current draft by saying that the DCs caused the problem by their past emissions and now want to thwart LDC growth. The draft basically says this can be handled by tax redistribution, but the dismissal is a bit too casual. You may want to address the

Dr. Joseph Stiglitz  
Dr. Sally Kane  
August 24, 1994  
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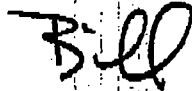
"legacy" issue directly by pointing out that if past emissions were all that were in question, there would be no problem: the rise from 280 to 350 ppm concentration has minimal effect. The real problem is much larger future rises, of which perhaps more than half will come from LDCs over the next century.

A related point is that the draft treats quota allocations in an antiseptic way without explicitly recognizing that there are potentially large distributional differences between tradeable permits and a carbon tax. The latter allocates by dollar voting; the former, by negotiated shares likely to take into account population and thus likely to have a more progressive outcome. My own view is that initial modest carbon taxes would be the right way to start, but if the problem proves as severe as it looks, eventually the international community will be pushed to some form of (tradeable) country carbon rights. Similarly, the current text rather casually refers to grandfathering, but especially over time this basis is inequitable without necessarily being efficient.

I guess a key task at this point is for your team to go through the other chapters carefully and see where there are points you want the other chapters to take up from your current text, so that whole sections from your chapter can be hived off to meet the space constraint without sacrificing key points of view.

I hope these comments are helpful, and I look forward to seeing you in Geneva.

Best regards,



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*W:SK*

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September 2, 1994

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Dear Dr. Stiglitz,

After reading Chapter I = the Overview and some of the other chapters of the first draft of IPCC WG III's assessment report, I faxed some comments to Jose Goldemberg and discussed these matters with him by telephone. He asked me to send my initial comments to you before the Geneva lead authors meeting 8-10 September.

First of all, may I say that I found some sections of the draft Overview especially those on the discount rates and on modifying national accounts, very valuable contributions.

Among my concerns are the following.

1. In a number of places the assumption is made that climate change damage is small overall, but costs of emissions reduction large. (e.g. in 1.1 Overview para 5, and section 1.1.1 para 3 and 4). These, as accepted views, are not very consistent with the Chapters on Social Costs of climate change, or with the Costs of Mitigation Chapter, which leaves fairly open the question of whether bottom-up modelers are right, in considering that energy efficiency measures can achieve some reductions at little cost or at some savings. In addition, recent modeling work by Richels and Edmunds suggest that if scheduling of emission reduction is optimal, stable concentration at reasonable levels can be achieved next century at less than 1% GDP cost.

2. Table 1 would be much more useful, in my view, if it showed Annex 1 Country emissions (i.e. including Russia and Eastern Europe) instead of Annex II countries. As it is, it tends to suggest incorrectly that developing countries are now the biggest part of the problem and leads later to criticisms of the FCCC, which will not be well accepted, that its main flaw is not requiring emission controls from the LDC's. Under 1.4.2 the FCCC is again criticized for not imposing emission control obligations on LDC's, whereas many would argue (with considerable justification) that its greatest failure was to not impose real restrictions on the industrialized nations. Perhaps both "failures" could be indicated.
3. The section on Sources of Uncertainty in the science (1.2.2) has many arguable assertions - we'd be best in WG III to just lift an appropriate few paras from WG I, I believe.
4. In my view the section on the Tangible Costs of Warming (1.3.1) and Intangible Costs (1.3.2) could be much shorter, leaving more detailed discussion to the Pearce et al Chapter on social costs. Also the references and discussions are far too heavily biased to U.S.A.
5. On Intergenerational Equity and Discount Rates (Section 1.3.4) there is considerable discussion in both the Equity Chapter - (will be completed by next week) and in the Chapter on Social Costs of Climate Change. The views are quite convergent and we should try to get an agreed statement on what we say about these issues - perhaps we can do so in Geneva next week.
6. Much of Chapter 1.4 General Responses, is very helpful, but the tone and outlook are a problem in some passages:  
  
e.g. the third para of Introduction says we'll discuss the difficulty in upholding the international treaty, rather than saying that we'll suggest some ways of overcoming the manifest difficulties.

The last para of 1.4.4 sounds a bit like a threat of developed countries to pull out of research if not matched by others - I don't think that this has a place in an IPCC report. This paragraph fails to recognize that, proportional to their GDP, great efforts are made by most developing countries just to measure their own climate and related resources and contribute these measurements to the world picture.

The 3rd and 4th paras of 1.4.6.1 need to be modified, I believe.

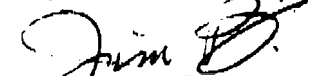
7. Lessons from the Past (1.4.6.2) contains a number of arguable judgements and some omissions. For example, contrary to 1.4.6.2 a, many scientists would argue that the case for greenhouse gas mitigation, or at least reducing fossil fuel consumption, is far stronger than was the scientific basis for CFC and acid rain controls when they were introduced. It should be noted that the Montreal Protocol of 1987 is pursuant to the Vienna Ozone Layer Convention of 1985. The "European protocols" on acid rain are, in part, pursuant to the ECE 1979 Convention on Long Range Transboundary Air Pollutants and the protocols involve North America as well as Europe (although U.S.A. and U.K. didn't sign). It is, in my view, probably not constructive in para 1.4.6.2 c to talk even hypothetically about "sanctions for non-members".
8. 1.5.4.5 on "No regrets policies" again belittles the major energy efficiency opportunities outlined by WT 6/7, by suggesting that government fossil fuel subsidies be removed only in Soviet Union, whereas - Canada, U.S.A. and Germany and several others, are among the worst offenders. The last sentence trivializes the energy efficiency argument. I have asked Prof. Goldemberg if he would provide an alternative draft.
9. Under Economics of Policy Actions, flexible regulatory measures are ignored and "command and control regulations" are probably rightly dismissed. However, many countries have excellent experience with energy targets (regulations) for appliances, cars, etc. which allow full rein to the innovative capability of industry, and are favoured by the public (e.g. 97% of motorists in Canada prefer CAFE standards as a means of reducing auto emissions) See also WT 8 Chapter. Given the political unpopularity of energy or carbon taxes, we should try to give some guidance to countries on how to make regulatory approaches most efficient, (e.g. Grubb 1991) or how to combine them with economic instruments.
10. Under Mitigation Policies for LDC's and their National Action Plans, Sections 1.6 and 1.7, why isn't there more attention to the options outlined in Goldemberg and Reddy's excellent book on this topic. The "leapfrogging" of technologies is dismissed far too quickly in paras 1.8.5.2 and should be a central point in LDC strategies. Prof. Goldemberg has been requested by me to provide some text for these sections.
11. In the discussion of sustainable development, there appears to be no recognition that increasing greenhouse gas concentrations are a clear sign of unsustainable development.

Perhaps I'm over-sensitive on some of these points, but I'm well aware that in presenting the report to countries, including many developing countries, we will be very much on the spot. Thus I think it is very important to get more input quickly from developing country authors of WT 1 and address the concerns noted above.

I will be in Ottawa until 5 Sept. 1700 hr and at Geneva Hotel des Nations Fax: 41 22 733 3884.

Thank very much and best personal wishes.

Yours sincerely,



James P. Bruce  
Co-chair, IPCC WG III  
cc: Erik Haites, TSU  
cc: Prof. Jose Goldemberg, Sao Paulo

From: John Reilly  
USDA/ERS

August 24, 1994

Some overall points:

- Much good material - broad ranging and ultimately covering the waterfront.
- As you indicated, still quite rough - much wordsmithing needed.
- I get a very U.S. biased feel from this document. Most of the references are US based economists. I suppose the U.S. has somewhat dominated the field of economics but you need to make an attempt to erase this apparent bias as much as possible or its going to be widely rejected internationally.
- You and Joe are perhaps more in tune with how the document is meant to fit with other chapters, but to me, this looks far more like an executive summary or (slightly) slimmed down version of the entire report than a scope chapter, i.e. you try to reach conclusions about each of the issues you raise which, I would think, should be left for the chapters. You somewhat fail to provide the broader picture in which this assessment fits and why economics/social science insights are important (exactly what broad questions does economics set out to answer that cannot be answered by physical science or other approaches) you have these answers, implicit in what you cover, but it does not come through clearly.
- I think you need to start out with some fairly straightforward, broader questions/issues that a broader audience can top into, thus providing a reason for the secondary chapters rather than answering all the questions so there is no need for the chapters, i.e. here is how I would start:

Climate scientist predict unprecedented rates of climate change resulting from accumulation of carbon dioxide, methane, nitrous oxide, and chloroflourocarbons and other gases in the atmosphere.

<sup>sp</sup>  
1) The accumulation of these gases is clearly linked to emissions of gases from various human activities including burning of fossil fuels, land clearing, various agricultural practices from use of refrigerants, and from land fills.

2) Climate change is one of a number of unintended effects of these activities. Other effects include ozone depletion, species loss, loss of forests and ecosystems, other air and water pollution, and the dispersal of hazardous and other waste.

3) The relationships are complex: CFCs deplete stratospheric ozone leading to increased UVB but less stratospheric ozone has been found to partially effect warming, sulfate emissions from coal use similarly lead to cooling perhaps masking the effects of trace gas

accumulation - efforts to control sulfate emissions and acid rain may, thus, "unmask" warming; policies and programs to limit erosions and adapt to climate change may conflict - shifting of agricultural zones may conflict with ecosystem preservation and migration and demand for land for agricultural or ecosystem preservation may conflict with efforts to produce biofuels or sequester carbon in standing fruits.

4) The issues are marked by uncertainty not only of the magnitude but of the direction of key efforts and of how different components of the system interact. Will warming benefit some areas and sectors while harming others; how much warming will occur and when; will change be gradual or marked by sharp local discontinuities and distinct changes in climate regions; can developed countries inexpensively shift to fossil fuel alternatives and can developing countries achieve goals of economic growth and human development without a heavy reliance on carbon based fuels.

5) To limit emission will require unprecedented cooperation among countries of the world; developed countries currently contribute x % but developing countries are expected to increase energy use and carbon emissions if they successfully develop reach of x % by the 2000 in some forecasts. How can the world reach a cooperative solution? How can it enforce the solution to which countries agree? How can it equitably share the cost of limiting emissions and the losses imposed by unavowed change?

6) The effects of gases omitted over the past few decades and over the next few will have effects for a century or more into the future. Our efforts to control trace gases are aimed primarily toward limiting potential effects on our children, grandchildren, and great-grandchildren. We face a difficult task in estimating and judging what aspects of climate and environment they will value and how best to preserve those aspects for them. If we take aggressive action to limit climate change, they may regret that we did not use the funds inclined to push ahead development more rapidly in Africa, to increase our understanding of human health such that we were better able to protect ourselves against diseases such as AIDS, or to have created a stable means of destroying, disposing, or containing stockpiles of nuclear materials.

• To fully assess these issues is now recognized to require unique new approaches for scientists from traditionally separate disciplines to work together to understand the complex processes and linkages, resolve uncertainties, and to devise effective responses recognizing that some aspects of climate change may be fundamentally unpredictable. The scope of Working Group II is particularly oriented toward summarizing: 1) Our understanding of the human focus leading to trace gas accumulations-how well can we predict future emissions?; 2) our understanding of how climate change will affect human - as natural systems are affected how do these "add up" to affect economic activity and human wellbeing; 3) approaches for how we decide what to do about climate change, particular given the uncertainties, unknowables, and unpredictable aspects of change; 4) how do we equitably share the burdens of climate change and

policies designed to use it both across current cultures and peoples across generations; 5) What are the cost and equity implications of various measures that have been proposed and 6) How does climate change and our responses to it fit within the broader, complex, and set of environmental problems, i.e. how do we achieve sustainable development?

- Economics has a well-developed theory for determining optimal and efficient policies. This theory has some severe limits and require strong assumptions, regarding compensation. I would start by discussing the basic economic framework for policy choice. I think if you do this first, then it is clear why economists care so much about estimating costs and valuing benefits.
- The economic solutions will conflict with politically determined solutions which can be seen as a process separate from the market for determining social choice. Having done the above, you might then go through more of the details but not as much as you do. For example, I do not think you need to review damage estimates for each section-this will be (should be) covered in the social art chapter. You only need to discuss it in a broad sense and why its important.
- In this mode, economic models contribute to the decision of what is the best level of control of emissions. A negotiated solution or solutions proposed by a political process might well diverge from this optimal response. Economic models and analysis can still be very effectively used to analyze the implementation of the policies and proposed policies and identify mechanisms that achieve negotiated solutions most effectively. For example, if a negotiated process were to determine a dangerous level of concentration that should be avoided, economic analysis could help identify how emissions targets should be phased in over time to meet such a target and might also recommend a system of tradable permits or the process of joint implementation to achieve the targets most efficiently. It might also provide an analysis of how the costs of the control policies would be distributed across different countries or income classes and thus provide input into the process of alternating emissions rights in an equitable manner.

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4

MESSAGE:

Sorry for the delay. I did my best  
with John's handwriting.

To: J. Stiglitz  
From: S. Kane  
Date: July 23, 1994

Here are the concerns raised by Jose Goldemberg and now addressed in document:

- \* Definition of sustainable development made more clear
- \* Expanded treatment of biodiversity
- \* Green gdp discussion expanded
- \* Intergenerational equity discussion modified
- \* Obligations under Framework Convention on Climate Change more even-handedly treated and expanded discussion of FCCC
- \* Energy Modeling Forum results cited
- \* R&D description expanded
- \* Geoengineering discussion modified
- \* **Carbon tax versus permits discussion greatly expanded to make more understandable to non-economists**
- \* Added work on technology innovation
- \* Modified discussion on population change
- \* Afforestation discussion expanded

Sections completely re-written for substantive improvements:

- \* tangible costs: sea level rise
- \* tangible costs: agricultural production
- \* intangible costs: loss of species
- \* adaptation
- \* top-down versus bottom up
- \* mitigation costs for less developed countries
- \* references checked and collected for all sections: will be completed in time for meeting on Tuesday
- \* entire section on economics of policy actions
- \* entire section on general responses

Sections that still need additional attention:

- \* top down versus bottom up
- \* entire section on paradigm choice: tie closer to climate change
- \* more detail on recent work on technological innovation
- \* integrated assessment
- \* health impacts

Sections that need LDC examples:

- \* national action plans from non-OECD countries
- \* mitigation actions
- \* policy instruments

For Geneva Trip  
9/8-10/94

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## **1.1 OVERVIEW.**

The natural science community has concluded that increased greenhouse gas concentrations in the atmosphere could lead to significant changes in the climate system, at a rate greater than any experienced over the past several thousand years (IPCC, 1992). Recent findings from climate models reinforce this conclusion. And at rates of climate change projected by general circulation models, significant changes to physical and social systems could occur. Therefore the risks posed by an enhanced greenhouse effect are potentially large.

In recognition of the magnitude of the potential costs associated with climate change and the need to minimize these costs at the global level, the Framework Convention on Climate Change was signed at a meeting of United National Conference on Environment and Development, held in Rio de Janeiro in 1992. The stated objective of this Convention is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (FCCC 1992). To date 163 nations have signed the Convention which entered into force March 21, 1994, ninety days after the date of the fiftieth ratification.

The IPCC has identified economic and social forces as important factors influencing the onset and duration of climate change as well as determining the range of responses that can be undertaken to address climate change.

This chapter provides a framework for thinking about global environmental problems in general, and climate change in particular. Building on the detailed information provided by the first two parts of this Second Assessment, important relationships are highlighted to provide guidance for understanding choices and tradeoffs that will be made in responding to climate change.

Good estimates of the net costs of climate change exist for developed countries, but not for developing countries, and not for countries isolated from international markets. Neither regional effects of climate change nor effects of the timing of climate change have been well studied. Therefore, although existing studies calculate small average costs from warming, the effects on some countries and regions could be much larger.

In evaluating the risks posed by an enhanced greenhouse effect, the timing of responses in the climate and human systems is critical. If the climate system changes have a long lag prior to their manifestation and quick social response is feasible, then the risks faced are minimal. However, short term response in the human system is inherently difficult; without new government incentives, inducing adoption of new efficient energy producing technologies, replacing the current transportation system dependent on fossil fuels with one that uses cleaner fuels exclusively, and changing land-use patterns in agriculture and forestry takes a long time, in some cases decades.

With uncertain but possible large risks and long lead times required for behavioral response, investments in measures that could provide safeguards become more desirable. Two general

types of measures can provide safeguards: mitigation and adaptation. In the first case, mitigation strategies reducing the rate at which greenhouse gases are being emitted into the atmosphere serve to delay or prevent climate changes. Examples of mitigation strategies are market improvements (such as removal of energy subsidies) that also reduce gases and government improvements that remove disincentives for efficient investments. In the second case, adaptation strategies serve to enhance societies ability to withstand changes in sea levels, flooding, and crop growth conditions and in some cases capitalize on positive opportunities.

Induced climate change is a global problem. The atmosphere is a shared resource and receptor of pollutants from everyone. Conversely, the pattern of altered climate conditions resulting from climate change are broad, truly on a global scale. The stakeholders in the problem span the globe: they include countries for whom control of gases on a per unit basis is expensive and countries that might suffer the greatest hardships in adapting to changes. Significant reduction of greenhouse gases at lowest costs possible (that is costs of effects plus policies undertaken) will require coordination at a regional and global level, recognizing that each country has unique circumstances and outlook that will determine its choice of policies.

**[need to add mention of Rio]**

#### **1.1.1 *Alternative Expressions of Goals***

The effects of changes in the climate system on human society's are uncertain, but are possibly large depending on the timing and the rate of change incurred. Human societies change over time, only partially in response to fluctuations in environmental conditions. Examination of effects (both benefits and costs) of climate change take place in the context of the dynamics of social change.

National and international approaches being undertaken (or suggested) to respond to the threat of climate change vary widely around the world. Approaches being discussed emanate from the circumstances particular to countries/regions including cultural traditions, natural resource base, political and economic structure, and population size and growth rate. For example, two countries similar in size and natural resource endowments may consider different types responses because of differences in cultural goals and differences in political systems. [Japan vs. Germany --example ??]

Alternate goals of human societies directly influence policy choice among countries/regions. While the goals are not mutually exclusive, there are often trade-offs. One universal goal is the desire on the part of each country/region to provide an improved standard of living for its citizens. All citizens need ready access to potable water, food, housing, education, and health care to be productive members of society. Economic growth lead to an improved standard of living as long as political and economic institutions are stable and conducive to these changes. Without continued economic growth, investments to reduce emissions could result in a slow-down or reduction in the standard of living, a trade-off developing countries would find difficult.

Sustainable use of resources, better known as sustainable development, is another goal of societies. While several definitions of sustainable development exist, a key requirement is that future generations be able to achieve a standard of living at least equal to that of the current generation. The challenge is to meet the goal in a world where population will increase significantly by the middle of the next century.

An ambitious goal is that of environmental equity. Equity considerations involve comparison of environmental effects both in time and space. For example, geographic equity could be advanced to populations with less income and less ability to mitigate/relocate away from adverse environmental conditions. These poorer populations could qualify for compensation to help absorb the adverse effects of climate change. A side issue of this goal is the question of whether the basis for decisions rests on a human-centered principles or environment-centered principles. Western tradition uses a human-centered paradigm, where adversely effected environment (either species or ecosystems) are considered only in its relation to human welfare. An environmental-centered paradigm treats the environment as having intrinsic value in itself, leaving open the possible trade-off between human welfare increases and perpetuation of a fragile ecosystem.

## **1.2 HUMAN ACTIVITY AND GLOBAL WARMING.**

For centuries, humans have altered the local climate, primarily through agricultural land clearing and urbanization resulting in changes in hydrologic regimes and localized temperature patterns (e.g. heat islands). In recent years, climate scientists have become increasingly concerned that human activities may alter the global climate as well through emissions of greenhouse gases into the atmosphere.

### **1.2.1 *Effects of Economic Activity on Climate.***

Economic activity influences climate through many pathways. Greenhouse gases are released through agricultural systems, fossil fuel production and consumption, and coolants used in air-conditioning and refrigeration. Economic activity can also enhance sinks for gases. One of the most well known activities is tree planting.

Particulate emissions from fossil fuel use also affect climate. While extremely short-lived (atmospheric residence time measured in days), the cooling effect of current levels of sulfate particulates, largely from coal burning, may have offset much of warming in the northern hemisphere during the last several decades (IPCC, 1992).

Land use changes affect climate. **[summarize findings presented elsewhere in SAR]**

#### **1.2.1.1 *Effects of climate on economic activity.***

A warmer climate would directly affect the temperature-sensitive sectors of the economy: agriculture, forests, and fisheries; and construction. Because of the risk of drought, arid and semi-arid regions are likely to be most vulnerable to warming. A warmer climate may also encourage insect populations, which is likely to decrease agricultural yields in some regions. On the other hand, increased CO<sub>2</sub> concentrations increase photosynthesis and the effect of water consumption in controlled settings, and may do so in farmers' fields.

A warmer climate may affect other sectors indirectly, through increased demands on water resources, and a possible increase in air pollution if energy consumption increases as a result. In addition, increasing storms that may result from a warmer climate would affect coastal areas including low-lying island states. Social effects of climate change can not be translated easily from changes in the physical systems. In the forestry and agricultural sectors, world markets would moderate the effects felt by individual countries or regions. Full effects are influenced by type of economy, participation in international trade, world pattern of changes in physical conditions, and flexibility in the economic systems to change as conditions change. Full effects in countries with less developed economies and economies in transition are less well understood. The range of effects are described in greater detail in sections 1.3.1 and 1.3.2.

#### **1.2.1.2 *Mitigation actions.***

Mitigation actions are targeted to reduce greenhouse gas emissions and if restrictive measure are taken concentrations in the atmosphere could ultimately be reduced. Actions include

reducing fuel consumption, switching to less carbon-intensive fuels, and reducing emissions of methane and other greenhouse gases. Given the limited understanding of the climate system, mitigation provides the surest measure for avoiding the consequences of climate change; but mitigation alternatives present economic, environmental, and health and safety consequences of their own. Alternative sources of energy (nuclear, solar, wind, biomass, geothermal) generate radioactive waste, toxics, and may affect fragile ecosystems and the lands of indigenous people.

#### **1.2.1.3 *Adaptation actions.***

Adaptation actions serve to lessen adverse effects or use opportunities created by an altered climate. Social systems evolve over time and naturally respond to changes in circumstances, whether they be economic, political, social, legal, etc. Enhanced adaptation can be facilitated through government actions. Government investment in R&D could be made to intensify development of new varieties of crops that can withstand significant changes in growing conditions. Populations of people could be moved to relatively less vulnerable areas. Investments in sea walls and changed specifications of facilities located along the coast would augment protection of low-lying coastal areas.

#### **1.2.2 *Sources of Uncertainty in the Links Between Human Activities and Global Warming.* (to be re-written by climate specialist)**

Atmospheric scientists are uncertain about how changes in today's emissions of various greenhouse gases will affect future atmospheric stocks of these gases and thus future radiative forcing (heat trapping ability). Scientists are also uncertain about how changes in radiative forcing will affect future climates. Major questions remain about the carbon cycle and therefore about the uptake of carbon in the ocean and in forests in the northern hemisphere.

Most international environmental agreements are made amid continuing scientific uncertainty; this will be particularly true of agreements on climate change. While scientists agree that greenhouse gas concentrations are increasing, they do not agree about the mechanism linking concentrations, temperature, and well-being. Thus, although scientists agree that some warming will occur, they do not agree on the speed of change, or the ultimate amount of change (IPCC, 1992). Important areas of uncertainty include the following: 1) How changes in today's emissions will affect future concentrations of greenhouse gases; 2) How changes in the time path of radiative forcing would affect future climate; and 3) How changes in future climates would affect human welfare.

Feedback loops complicate the analysis even further. Negative feedback loops in the atmosphere may offset much or all warming that would otherwise occur. For example, warming leads to greater evaporation, more clouds, more reflectivity, and thus less warming; also, increasing CO<sub>2</sub> may increase carbon sequestration through faster plant growth. On the other hand, positive feedback loops may accelerate warming: warmer oceans would likely absorb less CO<sub>2</sub>.

#### **1.2.2.1 *Uncertainties in atmospheric chemistry.* (review needed by atmospheric chemist)**

It is not known how today's greenhouse emissions will affect tomorrow's atmospheric concentrations. The major greenhouse gases remain in the atmosphere for a long time: except for methane, generally more than 100 years. Greenhouse gases accumulate slowly, but persist for a long time (IPCC, 1990a). Although fossil records show a close relationship emissions of carbon from fossil fuels and atmospheric stocks of carbon, scientists are unable to account for about 40% of the carbon released from fossil fuels and biomass (Albritton, 1990). This inability to account for carbon leads to uncertainty with regard to the future rate of uptake of carbon from the atmosphere.

Scientists do not yet know whether chlorofluorocarbons, on balance, add to radiative forcing or not, because the direct effect of radiative forcing is offset by an indirect cooling effect of stratospheric ozone depletion (IPCC, 1992). Far greater uncertainties exist with regard to other trace gases because known sources and processes of elimination do not explain recent rates of increase in the atmosphere. Recently attention has shifted to the cooling effect of sulfate aerosols, the role of carbon monoxide in the methane cycle, interactions of changes in climate with atmospheric chemistry (most chemical reactions are heat dependent), and terrestrial responses to climate change such as the release of methane from permafrost (IPCC, 1992).

Scientists do not agree on how to measure the warming potential of different greenhouse gases (IPCC, 1992). Although global warming potential (GWP), endorsed by the IPCC, is a useful concept in formulating comprehensive approaches to greenhouse abatement policies (Stewart and Wiener, 1990), some analysts have recently criticized the concept on the grounds that GWP implicitly sets the opportunity costs of an increment in radiative forcing equal for all periods in the future (Schmalensee, 1993). Actually, these opportunity costs are not constant, but vary over time; hence emissions reductions will impose different costs at different times. Finding an optimal path for greenhouse emissions requires comparisons of the discounted marginal damages of emissions from different gases. But GWP, the index most often used to compare greenhouse gases, is not based on such a damage comparison.

#### *1.2.2.2 Uncertainties in general circulation models (review by climate modeler)*

Even if future atmospheric concentrations were known, scientists could not yet confidently predict future climates. The major climate models do show modest agreement on the magnitude of the effect of a doubling of greenhouse gas concentrations on equilibrium global average temperature, with the range of estimates of temperature increases generally between 1.5 and 4.5° C; associated precipitation increases range from 7 to 15 percent (IPCC, 1992).

#### *1.2.2.3 Regional and temporal uncertainties.*

Uncertainties about the timing of effects, critical in evaluating the potential for human adaptation, require improved understanding of the transient path of climate change. Research is continuing on the inertia effect of the ocean which acts as a heat sink, delaying the realization of the full effect for many years. Failure to include realistic linkage with ocean models is one reason that the major models have so far generally overpredicted the climatic

effects of trace gas accumulation.

The socio-economic impacts of climate change are influenced strongly by localized climatic factors. Moreover, on a regional scale, direct and indirect effects influence human systems and unmanaged ecosystems. For example, warming may change actual level of the oceans (often deviating from mean sea levels), may change frequency, duration, and tracks of storms along the coast, may change inland conditions leading to changed pollution patterns along the coast, and may change features of agricultural systems along the coast through soil moisture and change in pest cycles. Regional fisheries could also be affected, by both human fishing policies and changes in natural conditions.

A short list of regional changes can be made. Sea level is expected to rise about 50 centimeters over the next century (**need latest figures**) for a 3 degree C temperature increase. Much work is on-going to translate these figures for individual regions around the world. Terrestrial effects can be described broadly. In general, climate models predict reduced soil moisture in mid-latitude continental areas, increased precipitation in high latitudes, and greater warming toward the poles.

The short list of accepted conclusions about regional effects makes it difficult to estimate social and economic effects of rising CO<sub>2</sub> concentrations. Integrated analysis that can evaluate the effects of climate change in the context of linked atmospheric composition, climate system lags, land-use, energy use and generation, population growth, and economic policies is developing, albeit with varying degrees of aggregation and model design.

#### 1.2.2.4 *Importance of extreme events*

Many of the costs of climate change are likely to stem from extreme climatic events: extra days of extreme heat or drought, increased severity of storms, etc. Conversely, some of the benefits will also stem from a reduction in extreme events: e.g. fewer days of frost in some cold regions. Further, many of the measurable effects of climate change will appear in years in which climate extremes would have prevailed even without an underlying warming trend. For example, agricultural yield studies show that warming would lead to only minor crop losses in a normal year but large losses in an otherwise hot and dry year; thus a warmer climate could turn a marginal year into a disaster. Similarly, 90 percent of soil loss due to erosion occurs during 1 or 2 major storms each year, and almost all coastal property losses occur as a result of extreme storms. In general, more extreme weather leads to disproportionately greater damages. By the same token, a warmer winter climate can disproportionately reduce the damages caused by extremes of cold.

Because of the importance of extreme events, an appropriate behavioral model often focuses on changes in the mean likelihood of an extreme event, or a change in the mean expected loss due to an extreme event.

#### 1.2.2.5 *Changes in variability.*

A changing climate may also change the variability of the climate; climatologists have no

firm evidence, however, as to whether climate will become more or less variable daily and seasonally. Realistic climate scenarios coupled with impact models that effectively treat climate will be necessary to evaluate the implications of changes in variability. For example, if the real limits to crop production are frosts and days of extreme heat, then models that incorporate only monthly mean temperature will be unable to distinguish between a climate with strong diurnal variation and hence more frequent frosts and very hot days, from a climate with a weak diurnal pattern. Whether and when climate models will be able to shed light on these detailed patterns of change is unclear. The inability to do so leaves us with substantial uncertainty in existing analyses.

The normal variability of existing climate also makes it difficult to detect any warming that might be occurring. The "signal to noise" problem makes it possible for observers to mistakenly consider a normal extreme event as evidence of a trend, or to fail to see a trend in a noisy data series. Because of the signal-to-noise problem, the scientific community is unable to indicate confidently whether extremely warm years of the 1980's are evidence of climate change or not.

### 1.2.3 *Uncertainties in Policy Responses.*

Uncertainties concerning policy responses center about 4 questions:

- 1) Do the behavioral assumptions of policy models reflect actual behavior of the parties involved?

Behavioral assumptions vary from one type of policy model to another. While each type of model attempts to incorporate actual behavior, most have difficulty in completely representing real behavior. Real life difficulties including the costs of information and the limits to fully rational decision making are often omitted from modeling efforts. It is also hard to model the qualitative differences that result from certain activities.

Policy models also are challenged by natural changes in behavior. It is always hard to make assumptions about how consumption and production behavior will change due to natural economic transformation. While much can be learned from past experience, there is no guarantee that a similar path will continue to be followed. As advances in modeling technique are made many of the difficulties may be resolved.

- 2) Will the policies actually adopted--as distinct from those considered in the analysis--be effective?

Policy analysts make simplifying assumptions in order to make their formulations computationally feasible, and consistent with current theory. For various reasons (**Cyert and March, 1963; Simon, 1957**), governments often violate the assumptions adopted by analysts.

- 3) Can an agreement be reached that leads to effective action among the parties?

Political scientists have found that achieving agreement on an effective low-cost policy is difficult. The negotiation process alone, for example, involves establishing new property rights and claims over the absorptive capacity of the atmosphere, while at the same time negotiating the level of control.

Compensation agreements will not be easily reached. Because it is difficult to predict what climate would have been had the stock of trace gases not been altered, it will be difficult to attribute particular climate events to parties responsible for altering the climate. Droughts, floods, and hurricanes are features of a normal climate. How much worse or how more frequent such events are because of human alteration of the atmosphere will be difficult to determine. Further, compensation depends on defining new property rights, a difficult goal.

Adaptive responses are easier to predict because they are regionally based. Nations and most other agents gain all the benefits of adaptive action, and suffer all the losses of failing to adapt. Adaptive responses depend, however, on regional predictions of climate change, and these are notoriously difficult. Timing of responses is important in relation to the speed of climate changes. If the lag in societal response is short relative to the change in climate effects, adaptive strategies (such as crop switching) are viable, and scientific uncertainties are relatively unimportant. If, however, response lags are long (such as construction time for new nuclear power plants), then scientific uncertainties gain importance.

- 4) To what extent can agreements be enforced, maintained, and updated as new information becomes available?

Countries will sign agreements for international cooperation when the gains from acting together exceed the gains from acting alone. In this respect, international environmental agreements are like producer cartels (Barrett, 1989). But just like cartels, international environmental agreements will collapse if cooperation demands large sacrifices from the cartel's members. More than any international agreement reached to date, new scientific findings will for many decades require significant modifications to agreements likely to be in place.

### 1.3 THE COSTS OF GLOBAL WARMING.

A changing climate imposes costs both tangible and intangible. In the developed world, the impacts are likely to be felt largely in agriculture and other climate-sensitive sectors of the economy. For most developed economies, these sectors constitute a small share of the total. For developing countries, the impacts will be more widely felt; first, because agriculture is a larger share of the economy; and second, because climate change can disturb an otherwise agreed upon economic development plan, diverting capital that would have been available for other important uses. Mitigation and adaptation may also claim resources from desired consumption paths.

#### 1.3.1 *Tangible Costs of Warming*

##### 1.3.1.1 *Sea level rise.*

Mean sea level has risen 10 to 20 cm over the past century, mostly the result of thermal expansion of the oceans. The IPCC projects mean sea level to rise 27 to 71 cm by 2070 (IPCC, 1990). Tangible effects could include inundation of wetlands and lowlands, faster coastal erosion, more coastal flooding, and increased salinity of bays and aquifers (Titus, 1992). Glaciologists have now largely dismissed earlier fears that a doubling of CO<sub>2</sub> could cause the West Antarctic Ice Sheet to break off and slide into the ocean, dramatically raising sea level.

##### 1.3.1.2 *Agricultural production.*

A warmer climate would hurt agriculture in some regions and help in others. Recent global studies find that Northern temperate regions could benefit, particularly at the low end of the climate sensitivities considered but low latitude areas could lose (Rosenzweig and Parry; Reilly, Hohmann, and Kane; Leemans; Leemans and Solomon). The climate scenarios considered in these scenarios were based on GCM results generating mean global temperature increases of 4.0 C to 5.2 C. The WG-II climate scenarios estimate mean global temperature changes likely by 2020 to 2050 to be .5 C to 1.2 C respectively (IPCC WG-II). The global studies show significant losses from climate change alone that are significantly offset by the direct beneficial effects of higher ambient levels of carbon dioxide on plant growth.

On balance most analysts expect that global agriculture can adapt without significant added cost in part because crop shifting and other adaptation by farmers and the moderating influence of trade in international commodity markets (Ausubel, 1990; Rosenzweig and Parry; Reilly, Hohmann, and Kane; Kane, Reilly, and Tobey). Some evidence suggests that global studies have not yet fully incorporated the full adaptive response of farmers and the agricultural system but these studies have not been conducted on a global scale (Mendelsohn and Nordhaus).

Focusing on global change in production tends to mask larger changes at the national and local levels. The potential for negative change for some areas has given rise to consideration of the factors that could contribute to vulnerability to hunger and famine (Downing, Kates,

and Chen). Poorer populations dependent on local agriculture resources for employment, income and food production are likely to be at a greater risk of famine should climate adversely affect agricultural production. It is recognized, however, that famine and hunger depend on how the rights to food are allocated, obtained, and protected in addition to basic capacity to produce food (Sen 1981, 1993; FAO).

#### 1.3.1.3 *Forests.*

A warmer climate implies both northward movement of forests and changes in forest composition. The result would be to reduce boreal forested areas and, by a smaller percentage, to increase tropical forested areas. On balance, doubling CO<sub>2</sub> concentrations would modestly reduce both standing biomass and forest area (Sedjo and Solomon, 1989). Some analysts also calculate an additional temporary decline in forest cover during the transition to a warmer climate (EPA, 1989); this decline could last for several hundred years, as more forest death occurs on southern edges than additional growth occurs on northern edges. Warming will likely increase forest growth rates in boreal and temperate forests and decrease growth rates in tropical forests. Higher CO<sub>2</sub> concentrations might increase tree growth, partially offsetting direct losses from warming.

#### 1.3.1.4 *Water resources.*

Some analysts conclude that a warmer climate would significantly reduce water supply (Gleick, 1987). If a warmer climate changes the precipitation balance toward more rain and less snow, the result will be earlier and greater runoff in spring and summer. For some regions, floods will increase yet available water will decrease. Most climate models now predict hotter and drier weather for the mid continents (IPCC, 1990a). If this occurs, the downward pressures on water supply will be intensified by upward pressures on water demand.

Because of the key role of local conditions, further generalizations are difficult. River basin runoff is the difference between precipitation and evaporation plus absorption (IPCC, 1990). Hence small variations in these three terms--each of which depends on the accuracy of regional climate forecasts--can make a large difference in the runoff.

A rising sea level would also inundate some small island nations, flood some low-lying coastal cities (e.g. in Bangladesh), damage coastal farmland, and contaminate water supplies (IPCC, 1990a).

#### 1.3.1.5 *Heating and cooling costs.*

A warmer climate implies reduced heating costs and greater cooling costs. At least for countries in temperate and cool climates, this would move the population-weighted average temperature closer to the ideal indoor temperature. All else being equal, heating and cooling costs, considered together, should decline. Complicating the calculation however is the thermodynamic reality that more energy is typically required to cool a room by 1 degree than to heat it by 1 degree. While electricity, with its associated conversion losses, powers air conditioners and fans, most heaters burn fuel directly, in both developed and developing

countries in both developed and developing countries. To estimate the effect of warming on total primary energy requirements for space conditioning, it is necessary to consider heating and cooling loads as well as overall efficiencies for converting primary energy input into delivered heating and cooling power.

Several factors complicate the analysis of global warming on heating and cooling costs, including the following.

- With global warming, sales of air conditioning will likely increase. To estimate the effects of warming on energy usage, it is necessary to take this effect into account. For countries with relatively little air conditioning in use, increased air conditioning sales could cause a large percentage increase in the amount of energy used for air conditioning.
- Because warm air can hold more moisture than cool air, global warming might increase the amount of water vapor stored in a unit of air to be cooled. This increase in water vapor will, along with the rise in temperature, increase the amount of energy required for air conditioning. Accurate information in the effect of global warming on water vapor is not readily available.
- The quantities of many fuels used for heating, especially biomass, are not accurately tracked. Without accurate data on baseline consumption, precise estimates in changes in the amount of fuel used for heating cannot be developed.
- In many countries, the price charged for fuel does not equal the marginal social cost of supplying the last unit of energy. This can occur for a variety of reasons including the existence of energy subsidies or the presence of a regulatory structure which prices energy at average system cost rather than marginal cost. For an accurate assessment of the social costs of warming, it is necessary to take the divergence between price and marginal social cost into account.
- The relative price of heating and cooling fuels is apt to change over time due to resource depletion and technological progress. To estimate the economic costs at the time when the warming will actually occur, it is necessary to forecast the changes in relative prices.

Relatively few studies of the effect of global warming on energy use exist. EPA (1989) studied the effect of warming on electricity used for heating and cooling in the U.S. In 2010, EPA estimated that a global warming of 1.0° to 1.4°C would raise electricity costs by \$3 to \$6 billion (1986 dollars) annually. By 2055, with a 3.7°C warming, EPA estimates the change in electricity cost at \$48 to \$73 billion (1986 dollars) annually.

Nordhaus (1991) and Cline (1992) have published estimates that estimate the effects of warming on both electric and non-electric energy costs for the U.S. These estimates build

on the EPA (1989) electricity cost estimates. Nordhaus (1991) finds that warming of approximately 3.0°C in a 1981-sized U.S. economy will increase electricity costs by \$1.65 billion and decrease heating costs by \$1.16 billion (1981 dollars). The net effect is a \$0.49 billion cost. Cline (1992) finds much larger costs. For a 2.5°C global warming in a 1990-sized economy, he reports increased electricity costs of \$11.2 billion (1990 dollars) and decreased heating costs of \$1.3 billion (1990 dollars). The net effect is a cost of \$9.9 billion.

A recent paper by Rosenthal, Gruenspecht, and Moran (1994) finds that global warming results in a net benefit to the U.S. economy. They use detailed data from the U.S. Department of Energy's Energy Information Administration to estimate baseline energy expenditures in 2010 for all fuels used for heating and cooling residential and commercial buildings. For a 1.0°C global warming, they estimate that cooling costs will increase by \$4.4 billion (1991 dollars) and that heating costs will decrease by \$9.9 billion (1991 dollars) in 2010. The net benefit is a \$5.5 billion; for a 2.5°C global warming, they estimate the net benefit is \$12.2 billion (1992 dollars). These estimates do not take into account the effect of warming on the market penetration of air conditioning. As a sensitivity analyses, they adjust for this effect and the net benefit estimates drop by approximately 20 to 25 percent.

It is difficult to compare studies outside of the U.S. because of differences in methodologies. The Intergovernmental Panel on Climate Change (IPCC) report (1992c) review the results of several studies of the effects of warming on energy. For industrialized countries, they find that the effect of warming depends on where a country is located. They cite a study by Nishinomiya *et al.* (1989) showing that warming will increase the demand for electricity in Japan. Another cited study by Gertis and Steimle (1989) shows warming in Germany will reduce heating fuel consumption and raise air conditioning demands. The net effect on German energy consumption is not presented. In the former Soviet Union, IPCC reports that Vladimirova (1990) finds warming will produce savings in heating from Moscow northward. For developing countries, the IPCC cites a study by Meyer and Sathaye (1988) showing that the electric demand is less sensitive in developing countries as compared to developed countries. The results of these studies are difficult to compare because they used different methodologies and many only considered a portion of energy end uses that are climate sensitive. More work is needed that applies a consistent methodology to different countries and climates.

### 1.3.2 *Intangible Costs of Warming.*

Intangible costs may include a loss of biodiversity, deforestation leading to soil erosion and enhanced surface runoff, water pollution, and soil degradation. These costs are social costs not adequately considered in the pricing mechanisms [nor in national accounting systems (see section 1.8.2)]. Current valuation techniques are crude. Some analysts, have found tangible costs to be small, and believe that the justification for costly, and more, restrictive actions rests on intangible costs (Nordhaus, 1993), which remain poorly understood.

#### 1.3.2.1 *Ecosystem damages.*

Population pressures have added to pressure on ecosystems, particularly in the third world. Climate change may exacerbate these damages, particularly in Africa, where environmental degradation has been particularly pronounced during the last 15 years (UN, 1989). During that time, arable land per person fell from 0.5 ha in 1965 to 0.3 ha in 1987, as overuse cut into soil fertility, and demand for land resulted in semi-arid land and other marginal cropland being pressed into service (World Bank, 1992). Already more than one-third of Africa is under the threat of desertification, mostly from mismanagement of land, and the overcutting of brushwood for fuel, rather than drought. If climate change increases the length and severity of droughts, however, desertification would be accelerated.

#### 1.3.2.2 *Species loss.*

Both the natural rate and human contribution to the process of species loss are difficult to estimate (EPA, 1989). It is even more difficult to predict the effects of climate change on species distribution. Uncertainty about the timing of changes in climate, the duration and type of environmental changes that would be caused by climate changes, and the combination of human and environmental driving forces would influence species diversity make the long-term projection of species change highly complex. Moreover, while some species may have difficulty adapting to climatic changes, opportunities for other species may open up.

#### *Background:*

Biological scientists are not sure, even to an order of magnitude, of the number of species on the planet (Wilson, 1988). Estimates of species loss are extrapolations based on rates of habitat loss. It is estimated that up to 70% of all species reside in tropical forests. The major sources of species loss is the conversion of tropical ecosystems to crop and pasture land (Forster 1992; Sandler 1981; Wilson 1988). Conversion of natural tropical habitats, therefore, contribute to both (a) increased release of carbon into the atmosphere and (b) species loss.

#### *Techniques:*

Although research on the valuation of biodiversity for diversity's sake is relatively new, there has been considerable research on the valuation of individual species or particular habitats. The value of species may be divided into use values and non-use values. Use values may be further broken down into: (a) *direct use value* - (eg. the value of direct consumption of a species or recreational benefits of a habitat), (b) ecosystem *functional value* (the value of the contribution of individual species to the maintenance of broader ecosystem health), and (c) *option value* (the value of potential future use value; there is an intrinsic value of keeping opportunities for future consumption open) (Fisher 1981; Fisher and Krutilla 1985). Non-use value may be divided into existence value (value placed on the knowledge that a species exists) and bequest value (value placed on leaving use and non-use values for future generations).

Of all these types of value, direct use values are easier to measure because they generate observable market prices. The cancer drugs vincristine and vinblastine derived from the rosy

periwinkle plant of Madagascar generated \$100 million in revenues annually (Farnsworth).

Various techniques exist for estimating other less tangible values. These include change in productivity methods, travel cost methods, contingent valuation methods, and inferring non-use values from market behavior (Fisher; Orians *et al.*; Munasinghe; Larson).

*Select findings:*

The change in productivity method attempts to estimate the value of productivity improvements (or cost reductions) attributable to certain species. For example, wild bramble (Rubus) in California provide a habitat for prey of wasps. The wasps in turn control a major grape pest. The coexistence of the brambles, prey and wasps saves grape growers \$40 to \$60 per acre in pesticide costs (U.S. OTA, 1987).

Walsh *et al.* surveyed 287 studies of travel cost and contingent value method estimates of the value of recreation demand in the U.S. from 1968-88. They list estimates of the net economic value per recreation day reported for activities involving consumptive and nonconsumptive use values of species. The values range from \$8 to \$102 (1987 constant \$) per person per day attached to different activities (e.g., hunting, fishing, nonconsumptive use). Median values of studies range from \$25 to \$55 for different activities.

Travel cost estimates of the value of rainforest reserves in Costa Rica imply a net present value of \$1,250 per hectare (Munasinghe, 1992). Travel cost and CV methods both yield estimates of the annual value of viewing elephants in Kenya to be about \$25 million per year.

*Existing Research Challenges:*

The size of nonuse values and the use of the CV method to estimate them has been the subject of considerable controversy in the economics profession (Larson, 1992; Ciccehetti and Wilde, 1992; Lazo *et al.*, 1992; Cameron, 1992). The estimation of nonuse values remains on the frontier of environmental economics.

Other approaches have been proposed in the environmental economics literature. Solow and others have pioneered new conceptual measures of biological diversity based on genetic differences between species; the contribution of a species to conservation values depends on its genetic distinctiveness as well as the effect that its extinction would have on the extinction probabilities of other species. Research on the measurement of biological diversity and on the economic value of its conservation (e.g., Weitzman, 1992, 1993; Solow *et al.*, 1993; Polasky, *et al.*, 1993; Solow and Polasky, 1994; Polasky and Solow, 1994) is relatively new and remains, for the most part, untested.

Another frontier of research is the calculation of measures of biodiversity at more aggregate levels. The value estimates cited above are all specific to particular species or localized sites. The construction of systems of environmental and natural resource accounts to complement standard systems of national accounts would provide information about how macro-economic impacts affect the biological resource base (Adger and Whitby, 1991;

Dasgupta and Maler, 1990; Forsund, 1985; Hartwick, 1991; James, 1985; Maler, 1991; Munasinghe, 1993; Peskin, 1981; Steer and Lutz, 1993) [see section 1.8.2 for discussion of revised national income accounts].

#### 1.3.2.3 *Amenity values.*

A warmer climate would improve human comfort in cold areas, and in the winter generally, while decreasing comfort in warm areas. Mearns et. al. (1984) [no reference] calculate a threefold increase in heat waves for a 1.7 degree C. rise in U.S. mean temperature. The question for policy analysts is, will net comfort rise or fall for a given rise in temperature? Schelling notes that people generally move toward warmer climates, and concludes that a warming would increase rather than decrease human comfort.

#### 1.3.2.4 *Human health.*

A warmer climate is expected to increase summertime deaths from heart disease, stroke, etc., and decrease wintertime deaths from pneumonia, etc. One study calculates excess deaths resulting from a warmer climate in 15 major U.S. cities (Kalkstein and Davis, 1989). Using these results, (EPA, 1989) finds that excess summer deaths would significantly exceed reduced winter deaths, and thus attributes a significant net cost to a warmer climate. Others, however, have concluded that no strong evidence exists for attributing excess deaths to higher temperatures (Cline, 1992).

1.3.3 *Nonlinearities and Irreversibilities.* (Needs to reviewed by Climate Scientist)  
Climatologists note the possibility of some very severe effects or extreme nonlinearities. If, for example, the deep-water conveyor current in the North Atlantic were very sensitive to additional fresh-water runoff, as has been suggested, then even a modest change in temperature could, by changing the conveyor, dramatically alter the Earth's climate. Other catastrophic events could include the release of methane from permafrost warming, or the breaking up of the West Antarctic Ice Shelf. Recent evidence from the Greenland ice cores hints that the Earth's climate has experienced changes of several degrees over just a few decades several times in the last 100,000 years.

Many damage effects rise nonlinearly with temperature changes. Thus, one study estimates that a doubling of sea level rise would imply a tripling of the resulting economic damages for the U.S. (Yohe, 1992). Some evidence suggests, though not conclusively, that warming would increase the severity and frequency of tropical storms (IPCC, 1990a).

While the costs of warming as generally calculated--both tangible and intangible-- fit neatly into the familiar cost/benefit framework, catastrophic change and irreversibilities would alter all existing relationships and necessitate major restructuring of the problem. Catastrophic change reduces the time available for response changing the calculus of benefits of action now versus action later. Similarly, irreversibilities in adverse effects forecloses opportunities for adaptive strategies adding weight to mitigation approaches. Whether catastrophic changes occur will depend in large measure on response times in the physical and social systems.

#### 1.3.4 *Intergenerational Equity.*

Climate policy raises particular questions of equity between generations, because future generations are not able to influence directly the policies being chosen today that will affect their well-being. Because climate change policy involves trading off near term costs (e.g., of emission controls) for long-term benefits of a reduced rate of warming, choice of a discount rate is crucial for rational policy making.

This debate is driven by alternative views of the intergenerational equity of discounting distant future benefits (Ramsey, 1928; Mishan, 1975; Sen, 1982). Questions have been raised whether investment not made to reduce greenhouse emissions (because the rate of return is inadequate) would in fact be made in the general economy where real returns are higher. Brown-Weiss (1989) argues from an ethical standpoint that future generations may have a right to enjoy resources at least as great as those enjoyed by today's generation.

Solow (1974) sees the max-min principle as a reasonable criterion for intertemporal planning decisions. Developed originally by John Rawls for application in the study of wealth distribution, the max-min criterion permits inequality in consumption between individuals (or in this case, between generations) only if it improves the position of the poorest individual. For intertemporal planning, this implies that consumption per head should be the same for all generations. With regards to exhaustible resources, Solow's work shows that earlier generations are entitled to draw down the pool of exhaustible resources so long as they add to the stock of reproducible capital.

##### 1.3.4.1 *Discount rate.*

Productive investments yield a positive real return, both in physical capital (e.g. machines) and human capital (e.g. education). That is, money productively invested today can be transformed into more money later, even after adjusting for inflation. Discounting converts each future dollar amount associated with the project into the equivalent present dollar amount that must be invested today in the general economy in order to yield the same future amount.

Greenhouse gas emission control may also be viewed as an investment: money is spent today on emissions controls today so that money may be received later in the form of reduced economic costs of global warming. If the real rate of return on investment in emission reduction exceeds the rate on investment in machines and education, then future generations would be better off if less were invested today in machines and education and more in controlling greenhouse gas emissions; the converse also holds.

Discounting allows the comparison between investment returns in a particular project and investment returns in the general economy. Social scientists have debated the precise rate to use for global climate analysis (Cline, 1992; Nordhaus, 1993). Different conclusions have been driven in part different assumptions about expected sources of financing, and about what return the funds would have achieved in the real economy.

**[expanded discussion to be inserted here]**

## **1.4 GENERAL RESPONSES TO GLOBAL WARMING.**

### **1.4.1 *Framework Convention on Climate Change.***

As of this date, the framework convention has been signed by 163 countries. On March 21 1994, ninety days after the date of the fiftieth ratification, the Convention entered into force. The objective of this Convention is as follow:

"...to acheive, in accordance with the relevant provisions of the of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference withthe climate system. Such a level should be acheived within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development in a sustainable manner." (FCCC 1992)

To achieve this end, all signatory countries are required to develop, among other things, inventories of anthropogenic greenhouse gas emissions and national or regional plans containing measures to mitigate climate change by reducing greenhouse gas emissions and enhancing sinks.

Beyond the requirements held by all signatories, countries with different levels of economic development are subject to different commitments. The countries listed in Annex I of the convention (all those listed below) have agreed to develop national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs. All those countries in Annex II (for this discussion, defined to be those in group A), have agreed to provide new and additional financial resources to meet the agreed full costs incurred by developing country Parties in complying with their obligations.

### **Annex I**

#### **Group A:**

Australia  
Austria  
Belgium  
Canada  
Denmark  
European Economic Union  
Finland  
France  
Germany  
Greece  
Iceland  
Ireland

Italy  
Japan  
Luxembourg  
Netherlands  
New Zealand  
Norway  
Portugal  
Spain  
Sweden  
Switzerland  
Turkey  
United Kingdom  
United States

**Group B:**

Belarus  
Bulgaria  
Czechoslovakia  
Estonia  
Hungary  
Latvia  
Lithuania  
Poland  
Romania  
Russian Federation  
Ukraine

Unresolved issues surround financial assistance and technology transfer. [**discussion of the Global Environmental Facility**]

**1.4.1.1 *Lessons from the Past.***

Negotiations on the climate convention and the initial discussions of follow-on protocols has been directly influenced by past experience of the world community with environmental agreements. Three agreements (or sets of agreements) are particularly germane to climate change because of their multilateral participation and the focus on problems associated with natural resources commonly shared by many nations (or the world as a whole): the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer (1990 and 1992 Amendments), the 1982 Law of the Sea Treaty, and various protocols (multi-lateral agreements) to reduce acid rain in Europe. Table 1 displays characteristics of several international agreements on environment problems and draws implications for successful negotiation of greenhouse gas reduction agreements.

Negotiations on climate change is made more difficult than the others because of the following considerations: 1) disagreement over the social costs of climate change; 2) range of

Table 1: ~~Global~~ International Environmental Agreements  
To be included in international section:-

|                          | Montreal Protocol                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Law of the Sea Treaty                                                                                                                                                                                                                                                                                                                              | European Protocols on Acid Rain                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Climate Change Convention                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Date of adoption         | September 1987, amended 1990, 1992                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1982                                                                                                                                                                                                                                                                                                                                               | First protocol adopted 1979 (effective 1983)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Framework Convention on Climate Change adopted in June, 1992. Negotiations continue and no protocols have yet been instated.                                                                                                                                                                                                                                                                                                                 |
| Length of negotiations   | 10 months                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 9 years                                                                                                                                                                                                                                                                                                                                            | The European policy responses to acid rain have evolved in an incremental manner since the EEC's 1979 Geneva conference.                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Ongoing                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Geographical coverage    | Global                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Global                                                                                                                                                                                                                                                                                                                                             | Regional                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Global                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Number of signatories    | 92                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 160                                                                                                                                                                                                                                                                                                                                                | 12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 163                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Ratified?                | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Yes, it is scheduled to enter into force Nov. 16, 1994                                                                                                                                                                                                                                                                                             | Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Yes, it entered into force March 21, 1994                                                                                                                                                                                                                                                                                                                                                                                                    |
| Administrative body      | United Nations Environment Programme (UNEP)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | International Seabed Authority (ISA) (this agency was newly formed by the Treaty)                                                                                                                                                                                                                                                                  | UN Economic Commission for Europe (ECE), European Community (EC)/European Union (EU) Council                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | International Negotiating Committee (INC) the Global Environmental Facility (GEF) has been named as the interim financial mechanism                                                                                                                                                                                                                                                                                                          |
| What is being regulated? | Ozone-depleting substances: CFCs, halons, carbon tetrachloride, methyl chloroform, HCFCs, HBCFC, and methyl bromide                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Navigational and territorial rights for coastal waters and mining privileges for common property seabed minerals.                                                                                                                                                                                                                                  | Acid rain precursors: SO <sub>2</sub> and NO <sub>x</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Greenhouse gases: CO <sub>2</sub> , CH <sub>4</sub> , CFCs, and N <sub>2</sub> O                                                                                                                                                                                                                                                                                                                                                             |
| Objectives and Timing    | <u>1992 Amendment</u> <ul style="list-style-type: none"> <li>CFCs and carbon tetrachloride: production and consumption phased out by 1996;</li> <li>halons: phased out by 1994;</li> <li>methyl chloroform: phased out by 1996;</li> <li>HCFCs: consumption frozen, by 1996, at 1991 levels and eliminated by 2030;</li> <li>HBFCs: consumption and production eliminated by end 1995;</li> <li>methylbromide: production frozen, by 1995, at 1991 levels;</li> <li>decided to increase capitalization of the LDC development fund from \$73 million to between \$340 million and \$500 million by 1996</li> </ul> | <ul style="list-style-type: none"> <li>establishes 200 mile EEZ;</li> <li>creates property rights for mining manganese, copper, nickel and cobalt nodules through 20-year permits;</li> <li>reserves mineral rights for developing countries;</li> <li>provides loans to developing countries for the development of mining technology.</li> </ul> | <u>1988 EC Directive</u> <ul style="list-style-type: none"> <li>specifies national SO<sub>2</sub> and NO<sub>x</sub> emission ceilings and reductions; (60-70% for major industrial members) from 1980 levels;</li> <li>sets emissions limits for individual new plants;</li> <li>existing combustion facilities will achieve goals in a staged sequence by 2003 (for SO<sub>2</sub>) and 1998 (for NO<sub>x</sub>);</li> <li>allows intra- and inter-plant emission offsets;</li> <li>obliges countries to provide details about compliance and implementation plans.</li> </ul> | <u>Article 2:</u><br>To achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level would be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. |

national interest among countries. Morrisette et al. (1991) identified five critical factors in achieving effective agreements on international environmental problems with insights into prospects for successful agreements on climate change.

- a. **Role of scientific and other knowledge:** The analysis of past protocols suggests that hope for early success in greenhouse gas mitigation should be tempered. In comparison to other cases, the case for greenhouse gas mitigation appears to be less convincing. The benefits of taking action are quite uncertain as the substantial costs of mitigation combine with an unknown social cost of "doing nothing" (unknown because the degree of warming is not known, much less its environmental consequences). Recommendation: Where uncertainty persists, estimates of impacts under different conditions should be sought so that the risks of climate change can be better assessed.
- b. **Flexibility:** In order to allow for greatest flexibility in a possible greenhouse gas mitigation strategy, we should: allow for differential responses governed by cost considerations; weigh the potential advantages of multiple-gas control strategies allowing trade-offs among emissions sources and sinks (as opposed to just CO<sub>2</sub> controls); and allow flexibility in compliance strategies (eg afforestation v fuel substitution).
- c. **Incentives for widespread participation:** Because of the global nature of the greenhouse problem, broad international participation in devising mitigation strategies is essential. A successful multilateral agreement will provide for both sanctions against non-members as well as inducements to states to join. In addition, equity concerns must be addressed (eg between developed and developing countries). As developed countries will "only go so far", any multilateral agreement will probably need to be as cost-effective as possible, subject to agreed-upon equity provisions.
- d. **The process of negotiations:** There are three important features of the process which a successful negotiation will include. First any credible agreement must build incrementally on its own history to establish a solid political foundation. Second, the process is greatly enhanced if there is widespread participation by countries as well as organizations and individuals on various sides of the issue. Lastly, international organizations may play a key role in bridging disparate national viewpoints. With respect to the issues mentioned above, the record so far on a greenhouse gas agreement is promising.
- e. **Perception and political action:** The role of public perception can be a critical factor in making a global environmental issue politically meaningful. While the perception of imminent catastrophe is not a necessary pre-condition to action, it can be a very powerful catalyst. Public and political perceptions of the risks

posed by global warming will likely be a strong determinant of the responses by different countries.

#### 1.4.1.2 *Joint implementation.*

Joint implementation, which allows for developed country Parties and other countries listed in Annex I to implement policies and measures to meet their commitments jointly with other Parties, is explicitly recognized in Article 4 of the Framework Convention. Both the motivation for the joint implementation concept and the criteria for making it operational and effective in contributing to the achievement of the objective of the Convention involve many issues that are amenable to economic analysis.

The potential value of joint implementation arises from the fact that the cost of reducing net greenhouse gas emissions may differ widely across countries. Joint implementation provides a mechanism for directing a given investment in net emissions reduction towards the most attractive opportunities to produce the maximum possible level of climate mitigation. Alternatively, a pre-specified level of mitigation can be met at a substantially lower cost with joint implementation than without it.

Joint implementation also provides an attractive way for parties that have not undertaken explicit commitments under the Convention to become involved in emissions reduction efforts that also further their economic development objectives. The importance of such involvement is underlined by scenarios suggesting that such countries will emit a growing share of total anthropogenic greenhouse emissions over the coming years. Joint implementation can also provide resources, including private sector investment, to supplement official financing available through the Global Environmental Facility and other sources.

Despite its potential for more cost-effective greenhouse mitigation, JI remains quite controversial. Among the concerns raised are that rich countries will use JI to evade their responsibility for necessary adjustments in their own behavior, that JI may substitute for resources that should be provided through official financing channels, that developing countries should not cede credit for their most attractive emission reduction opportunities to foreign sponsors, and that developing countries may lack the power and or experience to promote their own national well-being in the JI marketplace. Many of these issues are amenable to economic analysis.

The potential pivotal role of JI has been widely recognized, leading several countries, (including Norway, Denmark, the Netherlands, Mexico, and Poland) to undertake pilot JI projects. The United States Initiative on Joint Implementation (USIJI) seeks to develop the JI concept at the programmatic level in order to gain evaluation, implementation, and monitoring experience that could help to inform the development of internationally-accepted JI groundrules.

Key economic issues surrounding implementation of JI include:

- a. the establishment of baselines;
- b. the evaluation of market effects;
- c. the development of incentive-compatible contractual instruments to implement JI projects; and
- d. accounting procedures for stocks and flows of net emissions reductions.

The baseline issue gains its importance from the concern that JI sponsors not receive credit for offshore emission reductions that would have been implemented in the normal course of business in host countries that are not subject to an emissions cap. To provide such credit would potentially increase global emissions. An extremely strict "but for" test (for example, a requirement that a project be shown to have a negative present value absent consideration of its emissions reduction impact to qualify for JI) would avoid the problem of false credit. On the other hand, since many potentially profitable projects are routinely passed over given capital requirements and other constraints, such a test also exclude from JI many projects that are attractive in both economic and emission reduction terms that would not otherwise occur. Economics can help to guide the development of baselines that appropriately balance the risk of false credits against the risk of excluding the most cost-effective projects.

The evaluation of market effects is important given the need to consider net emissions impacts. For example, a carbon sequestration project that preserves or plants trees at one location may, through its effect on the forest product markets, have implications for forestry practices at other locations that fully or partially offset its direct effect. Keeping in mind that similar effects can also arise for purely national policies -- for example, successful energy conservation programs in one country can lower world market energy prices, thereby promoting increased consumption elsewhere -- market effects will need careful attention in the JI setting.

The need to develop incentive-compatible contracts is particularly important in the JI setting, given the uncertainties inherent in any JI arrangement that relies heavily on sponsor recourse to host country legal systems for enforcement. Particular ingenuity may be necessary with respect to instruments for carbon sequestration projects, given the concern to avoid any premature release of stored carbon.

Finally, a thorny accounting issue results from the fact that a ton of emissions avoided through more efficient practices is different than a ton of emissions captured in a sink. The former is permanently kept out of the atmosphere, while the latter has the potential to be released at a future date. Given the likely importance of both types of projects in the JI context, an ability to place both types of projects on a common basis is a high priority for JI evaluation purposes.

Many important questions remain to be answered about JI:

- a. What incentives would encourage JI investments?
- b. What actions would be granted JI credit against national commitments?
- c. How JI agreements would be monitored and enforced?
- d. How JI projects financing would blend with existing development aid?

[growing literature on joint implementation needs to be cited]

#### 1.4.1.3. *The Importance of International trade.*

Trade can significantly decrease the cost of any warming that might occur. In agriculture, for example, international trade helps determine the net economic effect of climate change on a nation, and alters comparative advantage and trade flows. Even when the net global economic impact is negligible or even beneficial, some countries will suffer significant losses and benefits. Tropical countries, for example, may be net losers even when the world as a whole benefits (Fisher et al., 1987; Reilly and Hohmann, Reilly, et. al., 1989; and Kane et. al., 1992).

Trade may also increase the difficulty of reducing global emissions. Suppose the developed countries agree to reduce emissions but the LDCs do not. To meet their obligations, the developed countries would effectively raise the price of burning fossil fuels. Some production of fossil-fuel-intensive products would therefore switch to nonsignatories, where energy costs would now be relatively lower (Edmonds and Reilly, 1983). Aluminum and chemical production, for example, has historically been sensitive to energy prices. Similarly, forestation policies may be offset by forest cutting elsewhere. Moreover, non-commercial fuel (fuel not bought and sold) may present its own problems, particularly in the LDCs. For example, India and China evidently use more coal than official consumption records indicate, because small users mine coal directly or obtain it through informal unrecorded channels. Efforts to limit emissions could increase the unrecorded share of energy consumption.

Greenhouse restrictions in one region may result in carbon-intensive activities simply moving to regions without these restrictions. Calculating these carbon "leaks" depends on uncertain parameters describing international trade, and on the structure of the model used (Whalley and Wiggle, 1992). Only a few models represent international capital flows, meaning that most models cannot represent industry relocation (McKibben and Wilcoxon, 1992).

#### 1.4.2 *Mitigation.*

Mitigation may take the form of limiting emissions, or of enhancing greenhouse gas sinks. Given today's limited understanding of the climate system, mitigation provides the surest measure for avoiding the consequences of climate change. Mitigation alternatives such as non-carbon energy sources present economic environmental and health consequences of their own. Moreover, mitigation actions have a specific time path that often complicates the

analysis. For example, reforesting all available land in the U.S. could significantly slow the accumulation of atmospheric carbon over the next 50 years, but not after the forests were full.

Many studies have measured the costs of mitigation actions, often using different model structures and assumptions, and yielding significantly different results. Recent model comparisons have compared economic optimization models, econometric models, and engineering optimization models, attempting to place the estimates on a common basis (EMF, 1993). These comparisons find wide differences in results among different models--often greater than the differences between various atmospheric or oceanic models--but conclude that between-model differences shrink once the models are put on a common basis. They also identify key variables that drive the differences in results, in particular economic growth, substitution possibilities, the rate of energy efficiency improvement, and the future availability of carbon-rich or carbon-free energy sources.

In deciding whether to undertake costly control measures now, governments will balance the immediate costs of action (noting that technical progress will lower the cost of future reductions) against the possibility that delayed reductions must be greater and therefore more expensive.

#### 1.4.3 *Adaptation.*

Adaptation actions enhance society's ability to withstand changes in the economic, social, and environmental system caused by climate change; where climate change has positive impacts, adaptation refers to actions that take full advantage of these effects. Adaptation will be a part of any response strategy, because proposed limitations on emissions growth will not stabilize greenhouse gas emissions. Thus the world will undergo some warming in even the most favorable case.

Human and natural systems have different rates of sensitivity and adaptability to climate change. In addition to sensitivity to change, adaptability of human systems depends on the lead time needed for human intervention in these systems and the time frame for systems to respond (US OTA, 1993). Adaptation is also influenced by the rate of change. For example, industry decisionmaking horizons and building schedules are shorter than the time frame within climate change would occur; those industries could be expected to adapt to climate change (US NAS, 1992). Lastly, institutions can encourage or prevent timely adaptation. Many human and natural systems transcend geographic, political, and economic boundaries leading to fragmentation that can impede adaptation.

Adaptation consumes real resources and human effort that could be put towards other productive uses; it entails opportunity costs. In this sense, adaptation may be counted among the tangible costs of climate change. However, the total tangible costs of climate change will be reduced through expenditures of these adaptation costs. That is because adaptation is undertaken to avoid the even larger costs that would be incurred without it.

The human genius for incremental adaptation to changing conditions is well known, and adaptive behavior may be expected to overcome many of the potential tangible costs of global warming (Schelling 1983, 1992; Council for Agricultural Science and Technology, 1992; Waggoner, 1993; Ausubel, 1991). Much adaptation takes place autonomously through the maximizing decisions of individual economic agents facing changed circumstances. The raising of houses on stilts by coastal dwellers (Bird, 1986) and the adoption of alternative crops or seed strains by farmers (Council for Agricultural Science and Technology 1992) are ready examples. Other adaptations, such as public works projects, research and development programs, educational initiatives, land-use regulations, and tax/subsidy schemes are organized collectively through public authority.

While the ultimate reductions that might be gained in the tangible costs of global warming through adaptation are not known, it is known that they are real and substantial. This complicates efforts to estimate the net tangible costs of potential future global warming.

#### 1.4.4 *R&D.*

Research and development can lead to greater understanding of uncertainties, reduce the cost of limiting emissions and enhancing sinks, and reduce the cost of adapting to any climate change that does occur. A complex network of research on climate change is evolving. Research programs on climate change have been initiated over the past few years at international, regional, national, and local levels.

As compared to the natural sciences, research in the social sciences does not have a rich history of international organization and coordination. There has been an increasing effort to focus on the "human dimensions" of global change (HDGC). These activities may be divided into a number of types. One European research programme - European Science Foundation's Environment, Science, and Society - has been completed. It has contributed to the evolution of approaches for economic and institutional analysis which have been applied to concrete cases: the North Sea and the Mediterranean. Both this research program and those of other institutions which operate in Europe (IIASA, OECD, UNU) have evolved to include or focus on HDGC themes. In the Asia-Pacific Economic Cooperation organization is reviewing the impacts and effects of global change in the Asia/Pacific region (cite).

Other global research programs are still in the planning stage, notably those of the International Social Science Council and the International Geosphere Biosphere Program (at least in the Core Projects with a recognized HDGC component). These organizations are also working together in the development of regional initiatives through the SysTEM for Analysis, Research and Training (START), for both the Mediterranean and Europe. In the Asia-Pacific region, the Asia Pacific Network for Global Change Research is being planned and is expected to serve as a framework within which sub-regional networks can coordinate their research efforts. The ISSC-HDP has also completed reviews of development of data availability for three thematic areas of HDGC. Finally, a global review other than the IPCC, focussing primarily on climate change -primarily its impacts, potential responses and related social science methodologies - are being undertaken through Battelle Pacific Northwest

Laboratories in the United States in conjunction with the ISSC.

[NEED OTHER EXAMPLES OF REGIONAL RESEARCH PROGRAMS WITH SOCIAL SCIENCE FOCUS]

#### 1.4.5 *Climate Engineering.*

Actions can be taken to intervene in the climate system to change the effects of anthropogenic forcing. These actions have been examined recently in the Office of Technology Assessment (1991) and the National Academy of Sciences (1991). However, unlike the case of reduction of human impacts through reduction of greenhouse gas emissions, i.e. mitigation strategies, climate engineering has yet to be systematically studied (Keith and Dowlatabadi, 1992). Engineering options include such measures as direct deep-ocean disposal of greenhouse gases, ocean-surface fertilization, or afforestation. Increasing aerosol concentrations or placing solar shields in the Earth's orbit to modify albedo represent a second type of engineering strategy.

Climate engineering could play an important role in planning future action, if uncertainties in the actual timing and amount of warming is considered to be significant. In this case, engineering options can be considered a "fallback strategy", allowing moderate responses to be adopted with the knowledge that should these prove inadequate, an alternative mitigation option is available ((Keith and Dowlatabadi, 1992).

## 1.5 FRAMEWORK FOR POLICY CHOICE

### 1.5.1 *Introduction.*

Climate change will impose one kind of cost on societies. Preventing or adapting to climate change will impose others. Because there are competing uses for scarce resources, governments may seek policies that minimize total costs: the direct costs of climate change that cannot be avoided, the indirect costs of climate change, plus the costs of policy responses. Determining the efficient response is difficult, however, both because of the complexities and the large uncertainties involved.

The costs of climate change and costs of policy response depend on two large systems -- the climate system and the economic system -- both extraordinarily complicated in themselves, and further complicated by the linkage between economic activity and greenhouse gas emissions. Because of these interactions, some individual and teams of researchers have begun to undertake an "integrated assessment" approach, which would integrate the economic and physical systems. While conceptually appealing, the resulting complexities require the use of many simplifying assumptions.

Uncertainty also surrounds key aspects of climate modeling. For example, very little is known about regional and temporal variations in climate that might be associated with a given increase in global mean temperature; this information is key to predicting the implications of climate change both for natural ecosystems and for climate dependent human activities like agriculture. Thus it is also key to formulating national action plans.

### 1.5.2 *Paradigms of Choice.*

Several paradigms for making rational policy choices arise from economics (broadly defined) and decision theory (need citations).

#### 1.5.2.1 *Standard cost-benefit analysis paradigm.*

In a standard cost-benefit analysis, one or a few possible policy actions are specified, and the future monetary costs and benefits flowing from each policy action are estimated. Then these future costs and benefits are converted into their present value equivalent amounts by applying appropriate discount factors to the monetary amounts that accrue in the future. Finally, the policy action with the greatest present value net benefit is identified as the best policy action to adopt (Musgrave, 1959).

This approach--at least in its basic formulation--has some inherent limitations. Most important, it does not handle uncertainty well, particularly when future resolution of uncertainty may cause mid-course corrections to a earlier policy which had been based on the information available at that time. This occurs because the possible policies in a cost benefit analysis are completely specified at the time of the decision, with no allowance for contingent future modification in response to new information.

Even in the absence of uncertainty, however, standard cost benefit analysis is limited as a

policy analysis tool for the climate change problem, because climate change is inherently dynamic. Since climate change is related to the stock of CO<sub>2</sub> in the atmosphere, the costs and benefits of additional emissions now depend on emissions decisions made in the past, as well as on those to be made later. This interdependence between policy decisions over time requires finding a dynamically optimal path of emissions. Standard cost benefit analysis, however, would typically involve only a comparison of several emissions ceilings, none of which is likely to represent a dynamically optimal path of emissions.

#### 1.5.2.2 *Dynamic optimization paradigm (Ramsey model).*

Whereas standard cost benefit analysis assumes an arbitrary emissions trajectory and estimates the costs and benefits of choosing that trajectory, a dynamic optimization approach first defines warming costs as functions of past and current emissions levels, and costs of emission control as a function of the level of control. Then, using an optimization algorithm, it finds an emissions trajectory that is optimal in the sense that emissions in every time period reflect an optimal balance between warming cost and control costs, given the (optimal) level of emissions in the past and future time periods. Most dynamic optimization analyses of climate change have been conducted in the context of Ramsey models of optimal economic growth (Ramsey 1928; Koopmans, 1967; Solow, 1970).

Implicitly, an optimal emissions trajectory appropriately balances the costs and benefits of delaying emissions reductions. For example, the cost of emissions reductions might be high in the short run and relatively low in the long run, when low-carbon or no-carbon energy sources are relatively cheaper. In this case, an optimal trajectory would involve higher emissions now, and lower emissions later relative, say, to some arbitrary target emissions reduction policy (Richels and Edmonds, 1993).

The chief limitation of Ramsey models (at least in their deterministic form) is that they fail to handle uncertainty. One may conduct sensitivity tests in which parameter values in a dynamic optimization are changed to see how strongly the optimal emissions trajectory is affected by such changes. Sometimes this will reveal that certain policies are relatively unaffected by parameter variations, and thus that uncertainty about these parameters does not matter for the choice of optimal policy. However, in the more general case, variation in parameter values will affect the optimal policy, and the implications of uncertainty about those parameter values cannot be determined from a (deterministic) dynamic optimization approach.

#### 1.5.2.3 *Decision theory paradigm.*

Decision theory can be viewed as an extension of dynamic optimization to incorporate uncertainties. As such, it overcomes this limitation of deterministic dynamic optimization (Pratt, Raiffa, and Schlaifer, 1965). It may also incorporate learning and sequential decisions. It does so, however, at the cost of considerable analytic complication, which often makes the problem intractable without simplifying assumptions to limit the range of uncertainty represented.

Decision theory methods generally require the specification and use of *subjective probabilities* of alternative *states of the world*. These probabilities are usually obtained through an interview process carried out with experts. The interview process is designed to elicit the experts' perceived odds of alternative states of the world. An expert quoting such odds for a particular state of the world should then be equally willing to take either side of a small wager that this state will prove to be true, when the payoffs to such a wager are consistent with his or her quoted odds, and assuming that the expert is risk neutral with respect to such a wager. A problem may arise if the experts' perception of risks differs from that of the general public. For example, the general public believes that risks from nuclear power accidents are much higher than experts believe, while the public perceives floods and earthquakes to be less risky than experts believe.

#### 1.5.2.3.1 *Weakness--analytical and computational complexity.*

The chief weakness of the decision theoretic approach is the degree of analytic complexity it generates. The analyst must identify all alternative states of the world and possible new information that may be learned, and assign subjective probabilities to them. Climate change involves two large and complex systems interacting over centuries; even supercomputers will fail to solve the problem when fully specified. Thus the analyst must make simplifying assumptions, the choice of which is an important challenge in itself.

#### 1.5.2.4 *Multi-attribute decision theory paradigm.*

One of the key difficulties in formulating a rational policy response to the climate change problem is that of expressing intangible warming damages, e.g. to ecosystems, as monetary costs. Where standard decision theory rolls this information into the utility function, multi-attribute decision theory attempts to avoid this difficulty, by employing more than just a monetary summary of warming damages, in formulating a policy response to climate change. To date, little empirical climate change analysis has followed this approach.

#### 1.5.3 *Considerations in Choice.*

Each of the choice paradigms discussed need to incorporate as much information as possible about human behavior. The understanding a policy maker has of the population's current desires and potential future actions will impact the efficacy of the policy decisions. While it is extremely difficult to assess how people's behavior will change, trying to include estimates about these changes is very important.

#### 1.5.3.1 *Learning.*

Two major studies have shown that rapid learning about the damage from a change in climate due to anthropogenic forcing would lead to shifting emissions control towards the future with higher rates of emissions in the near-term) compared to when learning is slower (Manne and Richels, 1992; Kolstad, 1993). In other words, quick resolution of uncertainty through learning provides information that would allow irreversible control investments to be phased-in as needed, rather than employing emissions control early without the possibility for reduction in the future. If investments in emissions control were easily reversible, optimal control of greenhouse gases are unaffected by the rate of learning (Kolstad, 1993). In

general, emission control investments tend to involve sunk costs.

#### 1.5.3.2 *Risk aversion.*

Subjective probabilities may be generated by a thought experiment in which an expert contemplates a wager as if he or she were risk neutral. Society as a whole is unlikely to be risk neutral, however, with respect to actual global warming outcomes, particularly catastrophic outcomes. Thus it is necessary to incorporate risk aversion into an analysis that seeks to identify an optimal policy with respect to emissions reduction.

Reflecting risk aversion in decision theoretic analysis is generally accomplished through the use of a risk averse *utility function* defined on income (or wealth) including the effects on income of emission control costs and global warming costs. Risk averse utility functions are characterized by declining marginal utility of income -- that is, at low levels of income, additional income has relatively high value, while the opposite is true at high levels of income. Consequently, an increment to income adds less to utility than an equal sized decrement subtracts from it, and a decision maker would not accept an actuarially fair wager.

Many different risk-averse utility functions might be used in an analysis of emission reduction policies. Analysts have debated which is most appropriate (Wilson, 1977). The connection between the degree of risk aversion reflected in the utility function and the appropriate discount rate may limit room for disagreement about these important parameters: A more risk averse utility function implies that the marginal utility of income declines faster as income rises. Since future generations are expected to have higher incomes than the present generation, using a more risk averse utility function implies a reduced willingness to sacrifice current income for future income, i.e. a higher discount rate.

How risk averse any society is depends on a variety of factors; its state of economic development, the immediate climate related threats it faces, and the ability to change economic activity. Understanding this risk position is important in any decision making paradigm as it will have large impact on the available policy solutions.

#### 1.5.4 *Concepts for Policy Choice.*

A number of useful concepts arise from the social science perspective. Some are little more than common sense, others are general concepts derived from optimization or decision theory, and still others follow from early applications of rational choice paradigms to the climate change problem.

##### 1.5.4.1 *Issues of Timing.*

The timing, predictability, and flexibility of policies introduced to reduce greenhouse gas emissions will significantly affect the cost of those policies. Capital stocks in the energy using and energy producing sectors of the economy change only slowly over time, while new technologies may take decades to come into common use. Consequently, the transition to a less carbon intensive economic regime will be less costly if the transition is predictable and made gradually. In addition, the transition will be less costly if it is accomplished using

flexible policy instruments. Economists note that a tax on carbon, for example, encourages emissions reductions, while allowing for inter-temporal flexibility in these reductions.

#### *1.5.4.1.1 Timing of critical policy decisions.*

Some analysts believe that emission reductions in the next few decades will be relatively expensive, since they must be achieved primarily by reducing use of oil and gas. Oil and gas emit less carbon than coal when burned, and cost less to produce. In later decades, however, emissions reductions may be relatively less costly if they can be achieved by substituting expensive but carbon-free energy sources for moderately expensive coal-based synthetic fuels. In this case, the optimal short-run policy would not differ greatly from the "no control" policy, even though the optimal long-run policy may differ sharply from the no control policy (Peck and Teisberg, 1993).

More generally, the cost to the economy will depend on the flexibility allowed in reaching an emission reduction path. For example, the goal of stabilizing emissions would cost far less if averaging is allowed among different years along the path than if emissions must not rise in any year (Richels and Edmonds, 1993); to the atmosphere, what matters at any given time is total concentrations, not the emissions path.

#### *1.5.4.1.2 Mid-course corrections.*

In many cases, a policy choice made in the near term may prove to be a mistake in light of information discovered later, but the mistake may be corrected later by relatively modest changes in the emissions path chosen after the new information has come to light (Lempert, Schlesinger, and Hammitt, 1993). Suppose that policy makers are uncertain about the extent of warming that will later turn out to be tolerable, and about the sensitivity of climate to CO<sub>2</sub> concentrations. Then whether they impose tight or loose controls over near-term emissions may not much affect overall costs of control. This results from the long time lag between emissions and temperature change; thus damages depend not on the flow of emissions, but on the stock of atmospheric carbon. As a result, mistakes made in one period may be fixed in the next period.

#### *1.5.4.1.3 Irreversibilities.*

In the presence of irreversibilities, uncertainties, and learning, an optimal policy may be cautious in the sense that irreversible commitments are postponed, pending the acquisition of better information. One study found that in the absence of threshold damage effects, the dominant irreversibility is not in the climate system, but rather in commitments to capital stocks to control emissions (Kolstad, 1993). In the presence of a threshold, however, environmental irreversibilities (large irreparable changes) may dominate capital stock irreversibilities.

### *1.5.4.2 Issues of Uncertainty.*

#### *1.5.4.2.1 Insurance and uncertainty*

In the presence of uncertainty, people insure themselves against many types of losses.

Insurance against greenhouse-related costs may take several forms, depending on the probability of the adverse outcome, the loss in value of the outcome, and the cost of insurance. Some urge prompt reductions in emissions as insurance against the risks of irreversible environmental damage. Others, noting that rational buyers don't buy insurance if the cost of the premium is too high in relation to the value of the possible loss, urge further scientific research before costly commitments are made for emission reductions. Still others urge development of new energy supply and conservation options, to reduce costs of mitigation and adaptation.

An optimal hedging strategy will depend on the uncertainty surrounding current knowledge, and the likelihood and timing of new supply, conservation, and adaptation strategies.

#### 1.5.4.2.2 *Carbon taxes and uncertainty.*

In the presence of uncertainty about costs and benefits of controlling emissions, a tax on emissions leads to a better outcome than an emissions quota if the marginal benefit function for control is flatter than the marginal cost (Weitzman, 1974). Some analysts have concluded that this condition holds for climate change policy (Peck and Teisberg, 1993; Nordhaus, 1993).

Suppose the function relating warming damages to greenhouse gas concentrations is smooth, i.e. with no critical thresholds. Then, because warming damages depend on the total stock of greenhouse gas emissions, damages are not much affected by any single year's emissions, and the *marginal damage* from the first ton of carbon emitted in a year is about the same as the marginal damage from the last ton emitted. By contrast, the *marginal cost* of controlling the first ton of emissions is about zero, while the marginal cost of controlling the last ton could be high.

#### 1.5.4.2.3 *Control policies under uncertainty.*

Under uncertainty, the optimal emission reduction policy may be more aggressive than it is if all uncertain variables are treated as known and equal to their mean values (Nordhaus, 1993; Peck and Teisberg, 1993). This is true primarily because of synergistic interactions between uncertain variables, since these interactions can produce extreme events with very high costs (Nordhaus, 1993; Frankhauser, 1993).

#### 1.5.4.2.4 *Portfolio of responses.*

Climate Change policy decisions can be compared to investment portfolio decisions. Numerous policy measures are available to limit the impacts of climate change. Countries will typically implement several of these policy measures since no one measure is clearly superior. The decision then is to choose the portfolio of policy measures best suited to the country's circumstances and to adjust the portfolio over time in response to new developments.

Governments will be making climate change decisions for most of the next century. This means that they have unlimited opportunities to adjust the size and mix of their portfolio of

climate change policies. The total resources devoted to measures to limit climate change (the size of the portfolio) and the mix of measures implemented (the mix of the portfolio) can be changed as often as governments deem appropriate.

In broad terms, the policy measures available to countries to limit climate change and its impacts include:

- climate research aimed at better understanding the causes and impacts of climate changes;
- technology research aimed at improving the cost-effectiveness of greenhouse gas mitigation technologies such as energy efficiency and non-fossil energy sources;
- joint implementation, technology transfer and other forms of international cooperation to limit climate change;
- phasing out existing policies, such as subsidies to fossil fuels, that reduce welfare and directly or indirectly increase greenhouse gas emissions;
- measures to reduce emissions, or increase sequestration, of greenhouse gases; and
- measures to adapt to the consequences of climate change.

The specific policy measures available vary from country to country; research capabilities vary, the inefficient existing policies vary, the costs and availability of measures to increase sequestration of greenhouse gases vary, the damages due to climate change and the measures for adapting to these damages vary.

Government decisions concerning the portfolio of climate change policies must consider the uncertainties associated with climate change and with the policy measures. The timing, magnitude and characteristics of climate change, particularly as they affect a specific country, are uncertain. The costs and effectiveness of policies aimed at limiting climate change are also uncertain. What will be the nature, magnitude and timing of damage due to climate change? What will we learn about climate change given a particular research budget? Will technology research lead to more cost-effective mitigation measures? Will other countries abide by their commitments to limit climate change? Such uncertainties can never be eliminated, but they must be considered in the selection of climate change policies.

A portfolio manager attempts to get the best return given a level of risk. The investor can also impose constraints on the portfolio to reflect his or her preferences. Countries likewise will select a portfolio of climate change policies that reflect, at least implicitly, a variety of objectives and constraints. A country may look for the economically optimal portfolio of climate change policies. However, considerations of the impacts of the policy mix on different socio-economic groups, international equity, and intergenerational equity are likely

to come into play. These objectives will have different weights and will vary from country to country.

#### **1.5.4.3    *Value of information.***

Better information leads to better decisions. Because of limits to current knowledge and the high cost of being wrong in either direction, the value of better information on climate change is likely to be great (Manne and Richels, 1992; Peck and Teisberg, 1993; Nordhaus, 1993). Most studies of the value of information assume that in the absence of better information, an optimal policy under uncertainty will be adopted. In actual practice, however, lack of good information may lead policy makers to extreme policies (such as "do nothing" or "control everything"). If suboptimal policies would be chosen with incomplete information but better policies would be chosen with better information, the value of improved information may be many times higher than estimated using the standard assumptions of optimal decision making under uncertainty (Peck and Teisberg, 1993).

#### **1.5.4.4    *Sequential dynamic decision making.***

Decisions will be made in the 1990s in the face of uncertainties about damages and long-run control costs that will not be resolved for decades. Major uncertainties will be resolved, and decisions made, during each of the next several decades. The optimal decision today depends in part on how future uncertainties will be resolved. The techniques of probabilistic analysis may be combined with dynamic optimization to incorporate results of future research into today's decisions.

#### **1.5.4.5    *No regrets policies.***

"No regrets" policies have positive net benefits independent of any considerations of climate change. No analysis is needed to determine that these policies make sense; they make society unarguably better off. The difficulty is in identifying them. Most analysts agree that certain proposals are truly no regrets, e.g. removing government subsidies to fossil fuel production in the former Soviet Union. In other cases, analysts are split. For example, consumers' choices of electric appliances or electric light bulbs are seen as clearly irrational by some, but rational by others.

## 1.6 ECONOMICS OF POLICY ACTIONS

### 1.6.1 *Long-term Objectives*

The objectives of the Framework Convention on Climate Change (Article 2) are the stabilizing the atmospheric concentrations of greenhouse gases at a level that would "prevent dangerous anthropogenic interference in the climate system," within a time-frame sufficient to permit adjustment of natural ecosystems, ensuring that food production is not threatened, and enabling economic development to proceed in a sustainable manner.

Nations are likely to reduce greenhouse gas emissions through changes to the energy sector. In many instances, countries will begin by focussing on CO<sub>2</sub> emissions. Three ways of reducing carbon dioxide emission include the following: reducing emissions from energy supply (e.g. fuel switching and increased conversion efficiency), increasing end-use efficiency, or shifting consumption patterns away from energy-intensive goods and services. The selection of methods depends on the type of energy systems in place and the range of opportunities presented for low cost modifications.

A variety of potential policy tools exist that can be used to achieve the long run goals. Using a mix of these policies might produces the most effective results. This section divides policy tools into three major groups: carbon taxes and tradable permits; market structure and government reforms; and investment in energy saving technology. The section concluded with a look at policy considerations for developing and transitional economies.

### 1.6.2 *Carbon Taxes and Tradable Permits.*

Several economic/fiscal are available to reduce emissions: 1) carbon taxes; 2) tradeable emissions permits, 3) subsidies, etc. Economists generally believe that economic incentives such as taxes or permits can reduce emissions at a lower cost than others (such as command and control regulations) because taxes and permits take advantage of information in the hands of producers, and of differences in control costs. Indeed, empirical work shows us that the excess costs associated with command and control regulations are typically very large (Tietenberg 1992).

#### *Choice of Economic Instruments (theory and implications):*

The choice between taxes and tradeable permits depends on the objectives of the policy maker and nature of the uncertainty about the marginal cost and marginal benefit curves for carbon emission reductions (Weitzman, 1974). Theory tells us that if the nature of the curves is known with very little certainty, but the marginal cost curve is known to be relatively steeper (i.e. a change in the level of pollution allowed brings about a greater change in the marginal costs of mitigation compared to the marginal benefits) then taxes should be the policy of choice. This is because, in this case, an erroneous estimation of the optimal tax rate will lead to a relatively small deviation from the optimal pollution level. On the other hand, an erroneous estimation of the optimal level of total emissions in a permit scheme will lead to a relatively large deviation from the optimal cost of the permits.

If the marginal benefit curve is known to be relatively steeper than the marginal cost curve, however, tradable permits are the better option. Here, an erroneous estimation of the optimal tax rate will lead to a relatively large deviation from the optimal level of emissions while an erroneous estimation of the optimal level of emissions in a permit strategy will lead to a relatively small deviation from the optimal cost of the permits.

If the marginal cost and benefit curves can be estimated with some accuracy, theory show us that the tradable permit strategy holds some advantages over the tax scheme. With permits it is not necessary to find both the desirable standard and the relevant tax rate (unless the regulating authority was willing to engage in an iterative trial-and-error process over time to find the correct tax rate; Tietenberg 1992); it is only necessary to define the standard and find a mechanism for issuing permits. Moreover, if there is inflation in the economy, the real value of pollution taxes will change, possibly eroding their effectiveness. Because permits respond to supply and demand, inflation is already taken care of. Taxes also require adjustment because of entry to, and exit from, the industry while permits adjust readily through market mechanisms. In addition, if the authority feels that the old standard needs some tightening they may enter the market themselves and buy some of the permits, holding them out of the market. Lastly, permits are also argued to have an advantage over tax systems with respect to 'technological lock-in'. Various factors present in the tax strategy contribute to this including the need for the authority to estimate mitigation costs and 'lumpiness' in mitigation investment (this 'lumpiness' occurs because taxes are often not announced well in advance nor are they guaranteed to be fairly stable for a given period of time). A permit system generally avoids these problems which enables more efficient investment in mitigation technology. (Pearce and Turner 1990)

While theory tells us when to use each type of market incentive, in addition to illustrating some important advantages of permits in ideal situations, there are some observations that Tietenberg (1992) draws from the real world (and its imperfections) that provide further insights:

- a. Permit trading is highly efficient unless permit markets are non-competitive or transaction costs are high. If the transaction costs associated with bargaining are high, taxes should be the policy of choice.
- b. When firms are price-setters rather than price takers (eg. when firms have some market power) and a permit system is used, efficiency will only be achieved if the control authority initially allocates the emission permits in an efficient manner. This, of course, would require regulators to have complete information on control costs for all sources - an unlikely prospect. Therefore, in this case, a permit system is not the best strategy.
- c. When high degrees of pollution controls are needed, permit prices or tax levels would be correspondingly high. As most tax and permit systems require companies to pay taxes or buy permits for all of their emissions (not just those above the optimal level),

the cost to the companies under these market incentives approaches would typically be greater than command-and-control regulations. In general, therefore, companies in areas where tight regulations are needed would tend to oppose market incentives approaches unless

- 1) all competing firms are under the same regulations.
  - 2) a "grandfathered" trading system is used. Grandfathering entails permits to be distributed originally in a manner such that emissions sources need only purchase any additional permits they may need to pollute more than their assigned emission standard.
- d. Permit trading integrates particularly smoothly into an existing policy structure that is based either directly (through emissions standards) or indirectly (through mandated technology or input limitations) on regulating emissions.
  - e. Permit trading works especially well for uniformly mixed pollutants (i.e. greenhouse gases).
  - f. Large permit trading areas facilitate greater cost reductions than smaller trading areas - again relevant to greenhouse gas emissions reduction policy.
  - g. **In regards to climate change, it seems clear that the pivotal role of CO<sub>2</sub> may require some fairly drastic changes in energy use on both industrial and personal levels. While permit trading may be the best strategy for industrial emission reduction, taxes may be more appropriate for the personal level (i.e. gasoline tax to reduce automobile use). Therefore, it seems that the ideal CO<sub>2</sub> emissions mitigation policy may be a mix of both permits and taxes. (Tietenberg 1992)**

#### 1.6.2.1 *Carbon taxes.*

Carbon taxes reduce emissions through three types of changes: fuel switching towards low- and no-carbon fuels; reduced demand for energy-intensive products; and reduction in the amount of energy used to produce a given quantity of energy-related services, such as lighting, space conditioning, or transport.

With carbon taxes, fuels with a high carbon content per unit of energy become relatively more expensive than low- or no-carbon fuels. The relative price of coal with a carbon tax increases more than that of other fuels because it has a high carbon content per BTU and a relatively low economic value per BTU. Renewable and nuclear fuels, which have no carbon, will become relatively less expensive than fossil fuels. Because of the long lifetime of capital goods, the full effect of fuel switching may not be felt for decades.

Whether reducing demand for energy intensive products or fuel switching is more important depends on many factors including the size of the tax, how long it is in effect, the price of alternative fuels, and technological progress in developing low- and no- carbon supply sources. Model results differ widely (cite).

Carbon taxes could also dampen economic growth, although researchers differ on the size of the loss. Two main studies provide insights into the root of the variance in estimates of the economic effects of carbon taxes: The Energy Modeling Forum Study (12) and the OECD comparison project. In each case, sophisticated sensitivity analyses are run by standardizing key economic assumptions along with use of common reference case scenarios of reductions.

*OECD Project on Economy-Wide Cost Estimates of Carbon Taxes:*

An OECD model comparisons project was conducted to compare economy wide estimates of carbon taxes. Time horizons, the key economic assumptions on growth, population and resource prices, and the reduction scenarios for six global models were standardized. The global models compared were the GREEN model, the IEA model and four North American models [Edmonds-Reilly Model (ERM), Global 2100 of Alan Manne and Rich Richels (MR), the Carbon Rights Trade Model (CRTM) of Tom Rutherford, and the Whalley-Wigle model] (Dean 1994).

There is significant variation in tax rates and costs for the same amount of emissions reduction among models due to differing assumptions regarding several key considerations. Several factors explain the differences between model results. The most important factors are:

- a. The degree of substitution between fuels - the ease with which producers and consumers can switch from high-carbon content fuels to low-carbon content fuels;
- b. Expectations about future energy prices and taxes;
- c. The speed of emissions reduction;
- d. The way in which revenue is recycled;
- e. The treatment of the removal of energy subsidies; and
- f. Assumptions regarding backstop technology and a host of other technical and economic factors.

Because of the varying approach to these questions, the range of estimated tax rates and costs are quite wide. For a 45% reduction in baseline emissions by 2020, the required tax would be in the range of \$150-\$325 per ton of carbon and the cost might be in the range of 1.5%-2.9% of world GDP. A 70% reduction in baseline emissions by 2050 could require a tax between \$230 and \$880 and a loss in world GDP of 2.4%-3.8% (Dean 1994).

The required carbon taxes and associated costs vary significantly across regions in all of the models. This indicates that the same proportional reductions in emissions across all regions would give rise to very different costs in different regions and would thus be globally inefficient - with great potential for savings in the global cost of reducing emissions through the use of emission trading between countries or regions (see section 1.5.2.1) or a global carbon tax.

Three insights emerging from the OECD study are (Dean, 1994):

- a. Small amounts of emissions reduction can probably be achieved at low cost;
- b. Large reductions can only be achieved at high tax rates (i.e. marginal reduction costs rise with emissions reductions).
- c. Carbon-free backstop technologies are likely to slow the rise of the carbon tax, or halt it altogether, if they are available at constant marginal cost.

***Energy Modeling Forum Project 12 (Impact of Carbon Emission Control Strategies) [THIS SECTION WILL BE EXTENDED]***

In a recent study at Stanford, the Energy Modeling Forum Project -12, the costs of holding carbon emissions flat at 1990 levels were assessed (**Energy Modeling Forum, 1993**).

Depending on which model is used, using carbon taxes to hold U.S. carbon emissions at 1990 levels could result in GDP losses in 2010 ranging from 0.1 to 0.7 percent of GDP in 2010, and 0.2 to 1.7 percent of GDP by 2030. Carbon taxes reduce GDP because they displace otherwise productive capital into investments aimed at decreasing carbon emissions.

The adverse impacts of a carbon tax on GDP were found to be partially or wholly offset by simultaneously reducing other taxes (revenue recycling). If tax reduction matches carbon tax receipts, then the package of tax changes is revenue neutral. Studies associated with the Energy Modeling Forum project indicate significant potential for mitigating GDP losses by reducing taxes on labor and investment. To date, researchers have focused on GDP rather than consumption, although carbon taxes may affect consumption and GDP in very different ways.

**1.6.2.2 *Tradeable Permits.***

Using permits, policy makers are able to decide what total quantity of emissions will be allowed. Then they may break this total amount up into smaller portions and distribute them in the form of permits. This allows the companies being regulated to pollute in accordance with the number of permits that they hold. The initial distribution may be performed through a variety of methods, such as an auction or allocation according to historical emissions levels (i.e. "grandfathering"). Once the permits are distributed among the companies being regulated, a market is set up wherein the companies may buy and sell the permits according to their plants' individual need to pollute. Plants whose cost of mitigation is low will find it relatively easier to abate pollution rather than buy permits. Plants with higher costs of mitigation will have a greater preference for buying permits than for abating pollution. The price of the permits, which are artificially created scarce resources, is determined by the market. With the use of tradable permits, companies have an incentive to improve the efficiency of their production, thereby reducing their emissions level, as they can sell excess permits on the market and generate revenue.

The literature has tended to classify three types of permit systems. The ambient permit system (APS) works on the basis of permits defined according to exposure at the receptor points. Each polluter, then, may face quite complex markets - different permit markets according to different receptor points, and hence different prices. The simpler emissions

permit system (EPS) issues permits on the basis of source emissions and ignores what effects those emissions have on the receptor points. Within a given region or zone, the polluter would have only one market to deal with and one price. Finally, there is the pollution offset (PO) system wherein the permits are defined in terms of emissions, trade takes place within a defined zone. However, the standard has to be met at all receptor points. The exchange value of the permits is then determined by the effects of the pollutants at the receptor points. The PO system thus combines characteristics of the EPS and the APS. (Pearce and Turner 1990)

### *Lessons Learned from Past Permit Trading Programs*

*(U.S. experience -- To be supplemented with international examples)*

Permit trading programs have been applied to air quality management problems in the U.S. since 1976. Several lessons can be taken from U.S. experience and applied to the design of tradable permit systems for reducing greenhouse gas emissions (Harper, 1994).

- a. Substantial compliance cost savings have resulted. Hahn and Hestor estimate that "bubbles" (the treatment of multiple emissions points as if they were subject to a single overall limitation) have saved industry \$650 million, and that "netting" (this tool allows sources undergoing modification to avoid potentially burdensome permitting requirements by reducing from other points in their facility so there is no net emissions increase) for modifying sources in nonattainment areas have saved \$500 million to \$12 billion. Carlin estimates that the lead banking provision (this allows the permits to be stored for future use by a source or for trading to another source) of the lead phase-out program saved refiners an estimated \$226 million. EPA's Regulatory Impact Analysis of the Agency's implementation regulations estimates that the trading regime will save 40%-50% of the compliance cost that industry would have incurred under a command-and-control program. ICF Resources estimates that the total savings are estimated to equal \$700 million to \$1 billion annually averaged over the program's life. (Harper 1994)
- b. Localized impacts of trading can be minimized but perhaps not avoided. In the literature on emissions trading systems, it is a common prescription that the scale of the environmental problem and the scale of the trading market should match. Following this prescription, the global warming problem would seem to be ideally suited to an international trading scheme, since greenhouse gases generally mix uniformly in the atmosphere.
- c. Trading approaches combined with compliance cost savings makes it possible to get agreement on tougher restrictions than would otherwise have been possible.
- d. Permits enable emissions caps to be identified and have provided important environmental security. The concept of tradeable permits incorporates application of a cap on total source-specific emissions or emissions in individual jurisdictions.
- e. Greater compliance verification is required. U.S. experience has shown that trading programs require greater verification than command-and-control systems for both

environmental and political reasons. Greater flexibility necessitates greater accountability. In the context of international trading, the technical verification problem could be compounded significantly due to the widely varying national infrastructures and capabilities to determine and enforce compliance. Verification may be made more difficult still if the tradeable permits program is complicated in terms of the number of chemicals involved, the numbers of trading parties, and the inclusion of forestation projects and other "sink enhancement" projects as generators of tradeable rights. For this reason, the ability to confidently verify results should be a central criterion in the design of an international program.

f. Emissions markets need to be facilitated. In general, once a trading program is underway, the less government involvement the better. The U.S. experience clearly shows that transaction costs, timeliness, and ultimately the incentive to trade are all negatively affected by close involvement of government in the trading process. At the same time, however, government can play a key market facilitation role through establishing centralized clearinghouses for information or even provide a banking or brokerage service to facilitate trades between private parties. These services would prove especially useful in the more complex international context.

g. Market certainty and regulatory flexibility must be carefully balanced. Emissions trading presents a classic public policy trade-off in the need to balance the competing objectives of providing certainty to the market and flexibility to ensure achievement of the environmental objective.

### 1.6.3 *Market Structure and Government Reform.*

#### 1.6.3.1 *Market reforms that also reduce greenhouse gas emissions.*

Unregulated competitive markets will not produce efficient allocations if the private and social costs of either production or consumption of a good diverge. Reforms that remove market distortions will increase market efficiency even without consideration of the benefits of reduced emissions of greenhouse gases.

*Removing Energy Subsidies:* Energy subsidies create the inefficient use of energy leading to increased CO<sub>2</sub> emissions as well as welfare costs. These subsidies are especially prevalent in developing countries. Shah and Larsen (1991) estimated world energy subsidies in 1990 to be \$230 billion. The study estimated that their removal would reduce global carbon emissions by 9 1/2% in addition to improving allocative efficiency thereby generating a welfare gain in subsidizing countries. Burniaux *et al.* (1992) obtained similar results using the GREEN model. Their results concluded that the elimination of all existing distortions on energy markets would yield an estimated increase in world real income of 0.7% per year in addition to cutting world emissions by 18% in 2050. (Dean 1994) Likewise, Unterwurzacher and Wirl estimated in 1991 that increasing prices in Poland, Hungary, and Czechoslovakia to world market levels would reduce emissions by 30%.

*Property Rights Reform:* Ill-defined property rights encourage overconsumption of resources. A clearer definition of property rights could be particularly important in helping to decrease deforestation, for example, while improving economic efficiency.

*Regulating Non-greenhouse Externalities:* Many activities that produce greenhouse emissions may also generate other kinds of pollution. For example, fossil fuel combustion releases conventional air pollutants; rush-hour auto use contributes to road congestion. Taxes, externality adders, congestion pricing, or tradable permits can correct these problems, resulting in lower emissions of both greenhouse gases and other pollutants.

*Unit Pricing of Waste Disposal to Encourage Recycling:* The "life-cycle" social cost of consuming a good includes its production plus its disposal cost. Most consumers, and many businesses, pay a flat fee for trash disposal; with a flat fee, the marginal cost of throwing away an extra pound of trash is zero. By moving from flat fees to unit pricing, the actual price consumers pay to buy and dispose of a good will more closely match its full life-cycle social cost.

*Pay-at-the-Pump Automobile Insurance:* In most countries, drivers pay their automobile insurance yearly or monthly. Once the premium is paid, the marginal insurance cost of driving an extra mile is zero, even though driving more does increase the chance of being in an accident. Alternatively, drivers could be required to pay a portion of their insurance bill at refueling. With pay-at-the-pump insurance, a tax would be levied on gasoline and earmarked to pay for insurance premiums. This would raise the cost of gasoline at the pump, but lower auto insurance premiums.

#### 1.6.3.2 *Government reform.*

Government institutions and regulations often can hinder the efficient use of energy resources. In many instances small government reforms can improve efficiency and reduce greenhouse gas emissions. One small example of this is the effort by some nations to overhaul their national accounting measures in order to address natural resource depletion and use of environmental non-market assets. Such a revised measure of national wealth would make the economic versus environmental trade-offs implicit in some policy decisions more readily quantifiable (see Section 1.8.2). Many factors influence the ability of governments to undertake reform including economic development needs, available natural resources, technology availability, and political feasibility.

Emissions may be reduced from current levels as economic restructuring occurs in transitional economies. For example, CO<sub>2</sub> emissions in the former East Germany have collapsed by at least 30% as uncompetitive heavy industry has more or less shut down in the process of unification (Grubb *et al.*, 1993).

Two examples of government reform have been included in the US' Action Plan (1993). The first encourages efforts to expand and improve natural gas markets through continued regulatory reform. These reform efforts include guidelines to allow greater natural gas use in the summer in coal- and oil- fired power plants.

The second action is a proposal to allow the private investment to fund hydroelectric generation improvements at government owned water facilities. This reform will improve the use of government resources, create energy savings and reduce greenhouse gas emissions.

#### 1.6.4 *Investment and Returns to Energy Saving Technology.*

Future emissions and the long-run cost of emissions reduction depend on the rate of technology advancement as well as the diffusion of currently available technologies. Private markets alone may invest too little in research and development, for the same reason that they may invest too little in other forms of information: the producers or discoverer of the information does not get all the benefits of the discovery.

Governments may increase resources devoted to technology development and the effectiveness of these investments by:

- a. Tax incentives to lower the cost of R&D while leaving project selection in the hands of the private sector. Maximum impact per dollar of tax expenditure is achieved by linking incentives to increased R&D expenditures on the margin, rather than to total R&D expenditure.
- b. Government-sponsored basic research. Private-sector firms may then apply this basic research to commercial products.

Researchers believe that a reservoir of relatively low-cost energy efficiency improvements remains to be exploited. However, a growing literature is improving the understanding of the extent to which technology improvements could lead to CO<sub>2</sub> emission reductions at low or negligible costs (US OTA, 1992; Grubb *et al.*, 1993).

#### *Bottom-up versus top-down controversy:*

A major difference of opinion exists about the cost of reducing carbon emissions (Grubb *et al.*, 1993). The macro-economic, or top-down, models have estimated reductions of GNP roughly between 1% to 5% to be needed to stabilize emissions (at 1990 levels ???). The bottom-up, or technology specified models, have been used to show the existence of significant reductions in the cost of energy as new low emissions technologies are adopted. Each of these types of models simplifies the problem in a different way, therefore understanding the modeling differences is critical to interpreting the differential results. Bottom up models identifies the total stock of potentially viable technologies. However, given the state of the art in modeling, the technologies are not fully characterized in the models. Current model limitations that influence the cost estimates from the bottom-up models include the following:

- a. Lack of consumer responsiveness (that is consumer behavior), e.g. resistance to adopting or investing in the technologies;
- b. Hidden costs, preventing automatic penetration in the market, not included;
- c. Institutional barriers (that in some cases can be eliminated through government policy

- changes) not addressed in models;
- d. Positive external effects to society associated with technologies that cannot be captured by the adoptees or investor.

Without incorporating these effects into the bottom-up models, they are apt to overstate the potential low-cost emission reductions that come from technological development, while the top-down models understate what is possible. Given the complexity of energy systems around the world, it is unlikely that any single modeling approach will give a reliable guide to the cost of reducing greenhouse gas emissions.

*Contribution of accelerated deployment of advanced energy technologies:*

An emerging area of research is the evaluation of the climate related value of advanced energy technologies. Analyses have been conducted to test the effect of the introduction and accelerated deployment of advanced energy technologies on the future rate and timing of anthropogenic climate change. Edmonds *et al.* (1994) has studied the importance of available advanced energy technologies such as those proposed by Johannsen (1993). Edmonds *et al.* use the Edmonds-Reilly-Barnes model for energy related greenhouse gas emissions; the MAGICC model for atmospheric composition, climate response, and sea level rise; the IPCC scenario IS92a (IPCC, 1992c) as the reference base case and five alternate energy scenarios that are far more advanced over today's energy supply and transformation technologies. The five energy scenarios are:

- a. advanced fossil fuel technologies
- b. advanced liquified hydrogen fuel cells
- c. advanced hydrogen fuel cells without liquified hydrogen
- d. low cost biomass
- e. accelerated rate of exogenous end-use energy intensity improvement

Combined, the energy technologies reduce annual emissions from fossil fuel use to levels that stabilize atmospheric concentrations below 550 ppmv (i.e. double the concentration prior to the Industrial Revolution). The tax rate, assumed to apply globally, used was the marginal cost of stabilizing fossil fuel carbon emissions in the reference case. With values reflected for only carbon dioxide emission reductions, the cost of global emission reductions grow from approximately \$35 (US) Billion in 2005 to \$230 (US) billion per year in the year 2095. With advanced fossil fuels, low cost solar electric power, low cost fuel cell vehicles, the present discounted value of adding low cost biomass fuel to the energy technology bundle is almost half a trillion dollars (US). The present discounted value of the advanced energy technologies taken together is \$1.8 trillion (US).

The introduction of advanced biomass energy production technology was found to play a key role in reducing emissions. Biomass energy at \$2.00/GJ growing to become the core energy supply technology by 2050 could significantly reduce emissions highlighting the potential role of technology development and deployment relative to that of fiscal and regulatory

intervention.

These results should be viewed as illustrative rather than predictive. The gains from introduction and deployment of advanced energy technologies is dependent on the order of the computation. Additionally, since  $\text{SO}_2$  associated with fossil fuel use has a cooling effect on the atmosphere, control of fossil fuel through technology is less effective than this type of study might suggest.

#### 1.6.4.1 *Factors influencing the adoption of technology.*

A number of factors influence the diffusion of new technologies. Several of the most important factors follow below:

*Information:* Considered as an economic commodity, information has high fixed costs and low marginal costs of production or dissemination. Also, information producers cannot appropriate all the benefits of their efforts, as every recipient of information instantly becomes a potential competitor to its supplier. Further, information is often concentrated in the hands of those who have an incentive to misrepresent it. Thus markets for information do not reflect the usual optimality conditions that characterize well-functioning competitive markets.

*Returns to Scale and System Effects:* Some technologies might be economically attractive at a large scale of production, but not on the much smaller scale on which they might initially be adopted. Other technologies exhibit dynamic scale economies: unit cost falls over time as a function of the cumulative output of firms or industries. Technology "networks" may also affect diffusion rates. For example, cars and trucks fueled with electricity, natural gas, methanol, etc., require a refueling infrastructure, which itself competes for resources with the conventional fuel infrastructure already in place.

*Risk:* Because decision makers may attach a risk premium to new technologies, an unconventional technology must have a significant cost advantage before it will be adopted.

*Cost and Availability of Capital:* The cost-effectiveness of individual technologies is sometimes computed using a social discount rate that differs substantially from the cost of capital to decision makers. Studies of implicit discount rates consistently show that households and firms use discount rates substantially above the long-term market rate of interest.

*Capital Allocation:* Real-world businesses may operate by rationing a fixed amount of capital rather than accepting all projects that pass a specified hurdle rate. With rationing, the opportunity cost of investment capital may significantly exceed the social discount rate, or even the rate at which capital is available to the firm in financial markets.

*Bounded Rationality:* Attention is itself a scarce resource. Managers and consumers may

focus product quality, labor productivity, human capital, etc., rather than energy efficiency.

*Hidden Costs:* Consumers value a range of attributes difficult to include in an engineering model. For example, auto buyers value not only first cost and fuel economy (which computer models can easily calculate), but also performance, safety, and durability, which they cannot.

*Divergence between laboratory and in-use performance:* Especially for new technologies, actual energy use often differs significantly from energy use calculated in the laboratory.

*Variation across individual consumers:* Engineering models generally assume an average consumer; actual consumers may display a wide range of characteristics and usage patterns.

#### 1.6.4.2 Historical trends in energy efficiency.

Historical trends in energy savings in various sectors of the economy, across countries, are compared below.

**Transportation Fuel Economy:** The projected rapid growth in vehicle use throughout the world, with implications for both global warming and local environmental issues, makes transportation fuel use a key leverage point in environmental policy. Fuel economy of new cars is converging across industrialized countries with widely varying fuel prices.

Researchers disagree, however, on how much fuel economy will increase in the coming decades, particularly in view of the importance of performance and other non-energy attributes that buyers value (U.S. National Academy of Sciences, 1992).

Use of alternative fuels is rising in some countries, driven primarily by concerns over smog and other local air pollution, problems rather than global warming. Vehicle fuels that may be attractive from a global warming perspective over the longer term include alcohol fuels from woody biomass, electricity from non-fossil sources, and fuel cells.

**Industrial Energy Efficiency:** A small group of industries (petroleum, primary metals, paper, chemicals, stone and glass) accounts for the majority of industrial energy use. These industries have led a steady improvement in overall industrial energy efficiency over the past two decades, especially in developed countries. Energy intensities have declined in parallel in all OECD economies over the past two decades. However, while improvement trends are broadly similar, differences in energy efficiency levels persist. These differences reflect a combination of: differences in energy pricing structures, differences in the composition of output within broad industrial classifications, and "pure" efficiency differences that reflect variation in age composition of the capital stock and production techniques across ACCEDE countries. Most developing economies and economies in transition use more energy per unit of industrial output than do the OECD economies.

**Home Appliances:** Appliance efficiency has increased dramatically over the past two decades, especially in developed countries. Both market forces and standards have driven

this trend, especially for refrigerators and space heating and cooling equipment, the greatest energy users.

**Land Use:** Because buildings have useful lifetimes of up to 50 years, the siting of buildings on land has important implications for energy use. For example, whether mass transportation and district heating can increase their market share will depend in part on population density.

### ***1.6.5 Mitigation Policy Considerations for LDC's and Transitional Economies***

Calculating the costs of CO<sub>2</sub> mitigation for developing and transitional countries present a set of complexities in analysis which differ in several ways from those related to the developed countries (Pachauri and Khanna, 1993; see Kononov, 1993 for transitional economy example). Most developing and transitional countries are still in the initial stages of establishing their economic infrastructure. Therefore, an element of opportunity cost in terms of foregone possibilities for economic development exist for those countries, which are generally not significant in the case of developed economic systems. Due to this, the cost of several mitigation measures which appears to be low in the short run could actually turn out to be large in magnitude over some time horizon. If a particular action results in reduction of CO<sub>2</sub> emissions at low direct cost, but over a period of time slows down the removal of poverty, then this could lead to large positive costs in the long run, for the following reasons:

1. Poverty and population growth have a strong and positive correlation;
2. Deforestation for fuel and fodder is also intensified by high levels of poverty; and
3. With limited modern infrastructure, a developing or transitional country may not have the benefits of joint products to the extent that a developed country might have, as say in the case of reduced air pollution from public transport. (Pachauri and Khanna, 1993)

#### ***1.6.5.1 LDC Mitigation Technology: Opportunities and Costs.***

The Asian Energy Institute has conducted a study with purpose to identify and evaluate existing and emerging technologies which may be implemented by 2000 to limit CO<sub>2</sub> emissions for different sectors in the participating countries which included a number of Asian countries and Brazil.

The study showed that there is vast room for emissions reductions in developing countries through improvements in energy efficiency and conservation, a shift to lower carbon fuels and renewable resources, and carbon sequestration through afforestation. Pachauri and Khanna (1993) provide data and insights for three developing countries.

#### **Bangladesh:**

For Bangladesh, the greatest room for improvement at the lowest cost comes from several

technologies. In the industrial sector, housekeeping could save 1.4 Mt-C at an investment of \$10.78 million. Also, improved combustion control could save .96 Mt-C at a cost of 12.09 Mt-C. In the rural residential sector, the use of cooking devices based on woody biomass could save 2.3 Mt-C at an investment of only \$10.6 million. Finally, afforestation could sequester 65.4 Mt-C at a cost of \$1,255 million.

#### India:

India has a different package of desirable technology changes. Again, in the industrial sector, improved housekeeping would save 28 Mt-C at a cost of \$380 million. In the electricity sector, 192.25 Mt-C could be saved with an investment of \$580 million in coal washing. Improving firewood and lighting (to tube fluorescent) in the domestic sector could save 43.2 Mt-C at a cost of \$520 million. Finally, the use of solar thermal systems in the deployment of renewable energy technologies could save 96 Mt-C with an investment of \$1,830 million.

#### China:

China has its best opportunity for low-cost emissions reduction in several technologies. The introduction of coal saving stoves could reduce emissions by 305 Mt-C at a cost of \$92 million. The retrofitting of existing boilers at a cost of \$800 million would save 160 Mt-C. Another 9.5 Mt-C could be saved with a \$114 million investment in pressurized fluidized bed. The retrofitting of existing kilns for a price of \$1,758 million would reduce emissions by 92.5 Mt-C. Finally, the use of hydropower and nuclear power would save 1,992.5 Mt-C at a cost of \$44,816 million.

#### *1.6.5.2 Economy-wide Cost estimates for LDC's and Transitional Economies.*

Grubb *et al.* (1993) provide a survey of work done regarding the cost of limiting CO<sub>2</sub> emissions.

#### LDC's:

There have been few integrated system-wide cost estimates for CO<sub>2</sub> emission reductions in developing countries.

The GREEN study, conducted by Burniaux *et al.* (1992), found that an 85% reduction in CO<sub>2</sub> emissions from baseline by 2050 would result in a 1.9% reduction in GNP from baseline. The same study concluded that a 63% CO<sub>2</sub> emissions reduction by 2050 in Brazil would lead to a loss from baseline in GNP of 1.8%.

Two Blitzer *et al.* (1990) studies examined CO<sub>2</sub> emissions stabilization in Egypt and came up with the very large potential GNP losses of 2.7%, 15%, and 19% by 2002 for reductions from baseline of 15%, 35%, and 40%, respectively. These studies, however, are based on a short-run macro-economic model of the Egyptian economy that is modeled with very limited capital mobility between sectors, and with oil gas as the only future energy supply options. It recognizes none of the technical inefficiencies in the economy. Except the modest mitigation available from switching from oil to gas, emissions savings can only be achieved

by reducing energy consumption, which, given the constraints on capital mobility, can only be achieved by reducing economic activity or changing its structure.

#### Transitional Economies:

China and the former Soviet Union were included in the OECD comparisons project discussed in 1.6.2.1 above. The four studies included in the project (**Barns et al. 1992, Oliveira Martins et al., 1992, Manne, 1992, and Rutherford 1992**) come up with a range of results for each country. The estimates of GNP reductions from baseline for China for a 45% reduction by 2020 range from 0.7% to 2.8%, depending on the model used. The estimates of GNP loss for a 70% reduction from baseline emissions by 2050 range from 1.5% to 4.3%. Likewise, the estimates for the former Soviet Union vary as well. For a 45% reduction from baseline CO2 emissions by 2020, the estimates for reduction from baseline GNP range from 0.9% to 3.1%. The estimates of GNP loss for a 70% reduction from baseline emissions by 2050 range from 2.3% to 6.4%. The reasons for the variation among the studies is discussed in 1.6.2.1.

A study conducted by Leach and Nowak (1991) found that a reduction from baseline CO2 emissions of 37% by 2005 could be done in such a way that there would be a possible net gain to GNP. This is a byproduct of the economic restructuring process. (For example, the highly inefficient energy subsidies would be removed, see section 1.6.3.1.)

## 1.7 NATIONAL ACTION PLANS: AN EXAMPLE OF POLICY CHOICE

### 1.7.1 *Overview*

Over the past few years a growing number of countries have produced documents that describe their national plans to respond to climate change concerns. These documents demonstrate the effort and commitment that these countries are concentrating on climate change issues.

All of these documents seem to follow a similar form. They usually begin with some discussion of the scientific evidence available that necessitates a national response. Then the report will explain the nation's goal or other targets for greenhouse gas reduction. Finally the report outlines the actions necessary to achieve its goal. These actions vary from a very general discussion of the types of activities to be taken to very specific government or private sector responses.

For some countries [examples .. Germany, Netherlands, Australia, and others] these reports represent a continuation of their commitment to the issue. Many countries have extensive programs already underway to improve energy efficiency as well as other activities to reduce greenhouse gas emissions. Often these reports provide a useful forum for incorporating their existing programs into a document that will be useful in preparing their first full communication with the Conference of the Parties (CoP). These communications with the CoP will require that each nation cover in detailed information on emissions and sinks both in inventories and projections and details on specific measures that will be undertaken to attempt to achieve the commitments in the Convention.

### 1.7.2 *Components of Plans*

The actions in these plans fall into five categories:

- market efficiency improvements;
- government efficiency improvements;
- new technology development and international cooperation;
- sink enhancement;
- and research.

Each country in developing its plan selects a mix of actions from these areas that best suits its goals and abilities.

**[will be fleshed out in more detail on types of actions and country mixes]**

### 1.7.3 *United States' Climate Change Action Plan -- Example #1*

One of the most complete plans in terms of blending actions from all five areas is the United States' Climate Change Action Plan (CCAP). The CCAP presents the measures or actions that the United States seeks to use to meet its greenhouse gas reduction goal. The CCAP is unique in that the descriptions of the proposed measures and their effect is much greater than in any other of the available plans. Of the 46 measures listed, almost all have been evaluated

in terms of costs and effectiveness. Most of the proposed actions will be achieved by shifting existing budgets, however, some of them may require further Congressional approval.

The CCAP was designed to be comprehensive, targeting all sectors of the economy and all gases, cost-effective, and quickly implemented. The plan also reflects the desire of the U.S. to build a productive relationship between government and the private sector. It seeks to rely on public-private partnerships and cooperation instead of command and control mandates. The plan demonstrates how the U.S. is trying to leverage limited government resource to produce efficient and effective results.

The five categories of actions are represented in the actions to reduce greenhouse gases. The plan is effective in trying to achieve a balanced mix of measures that impact every sector of the economy. The measures to reduce CO<sub>2</sub> emissions are grouped into five areas; commercial demand actions, residential demand actions, industrial demand actions, transportation demand actions, and energy supply actions. There are also actions aimed at other greenhouse gases and CO<sub>2</sub> sequestration.

The commercial actions demonstrate how the government can work with the private sector effectively. There are several existing programs designed to help companies invest in energy efficiency in order to improve their energy performance. These programs will be expanded to continue their work of providing technical assistance, sponsoring research in emerging technologies and provide funding for new energy management programs.

The residential actions aim to make homes and home appliances more energy efficient. One program is a new partnership between the government, non-profit groups, environmental groups, and utilities to accelerate the commercialization of advanced energy efficient appliances. There are also other actions that will produce energy efficiency standards for residential appliances, and that will encourage the development of updated building codes to increase the overall energy efficiency of homes.

Industrial actions include a program to accelerate the commercialization of industrial equipment. Actions in this sector also include an innovative Motor Challenge program and efforts to encourage the greater use of recycled products, which consume less energy, in manufacturing process.

The most notable transportation sector action is the parking cash-out proposal. This proposal will provide workers the option of receiving the cash value of employer paid parking. Employers will not see an increase in the cost of doing business and employees now will have a financial incentive to reduce solo commuting where alternatives exist.

Energy actions include efforts to enhance natural gas utilization, enhance renewable commercialization, improve performance of existing zero emission technologies, and improve energy efficiency. The most interesting proposal would allow private developers to invest in

upgrades at Federal hydroelectric projects. Allowing this investment will increase the generation capacity at these facilities that institutional barriers have prevented. This proposal demonstrates how successful public-private cooperation can help resolve government inefficiencies.

#### **1.7.4 *The UK Climate Change Program ... Example #2***

While the CCAP may be the most detailed in its exposition of the costs and benefits of individual actions, other equally detailed documents are beginning to emerge from other countries. The United Kingdom's Climate Change Programme (CCP), its Report to the Framework Convention on Climate Change, is a good example.

The UK's program is a blend of the five plan components mentioned in Section 1.7.2. The CCP thoroughly describes the steps that the UK is taking to meet its emissions goals. Like the U.S. the central focus is on developing actions that achieve goals as cost effectively as possible, especially in the area of energy efficiency where savings can produce economic and social benefits as well. The Programme generally favors economic instruments rather than regulation, seeking to remove market barriers to efficiency, provide better information about investment opportunities, and ensure that prices reflect environmental costs. The CCP also emphasizes the importance of government partnerships with industry and environmental groups in successfully meeting the UK's objectives.

Most of the CCP's effort is aimed at energy efficiency. Measures are divided into five areas; energy supply, consumer consumption, business consumption, public sector use, and transport sector use. The general philosophy for the energy supply sector is to stimulate development of new and renewable sources wherever they are economically attractive and environmentally acceptable. Publicly owned utilities are being encouraged to use renewable sources. The government is also sponsoring a program of research, development, demonstration and dissemination of new and renewable energy technologies. Other programs will focus on improving technology that combines heat and power generation, using waste heat from electricity generation more efficiently.

The consumer sector initiatives are to make sure that households have the appropriate price signals and that they are provided with information, advice and encouragement in moving to more energy efficient consumption. The strongest price measure is the introduction of a VAT on domestic energy. The government is also taking steps toward ecolabelling and working on new standards for buildings and appliances. Other programs give financial incentives for installing more energy efficient systems in the home.

The business sector measures are efforts to use market incentives and encourage businesses to take voluntary action. The primary effort is the Make a Corporate Commitment Campaign. This campaign seeks to get top management commitment to energy efficiency from private and public sector organizations. The CCP presents a long list of companies and organizations that have made commitments. There are also many programs to help

businesses with advice and information, as well as special programs to help small businesses.

The CCP promotes the idea that the public sector must take the lead in working toward energy efficiency. Government departments are working to achieve a 15 percent energy savings target by 1996. Additionally local authorities are to improve the energy efficiency of the housing stock they own.

There are several innovative measures that are being evaluated in the transport sector. The plan includes more basic efforts like increasing the transport fuels duties, promoting auto fuel efficiency activities, and providing subsidies for regional rail and public transport. However, what stands out are research efforts into congestion pricing on roads around London, experiments in electronic tolling on motorways, and new programs to limit speeding.

The CCP also has a variety of measure aimed at reducing methane emissions. Most of these efforts target waste minimization in some form. Especially notable is the goal to recycle half of all recyclable waste by 2000. The government hopes to make producers of products that ultimately become waste responsible for the waste. There are also measures aimed at improving landfill standards, possibly even a levy of some sort. Other measures focus on livestock and coal mining.

The Programme identifies many types of assistance for developing countries and countries with economies in transition. Bilateral assistance is available for energy efficiency, forestry, and technology cooperation. There are also several multilateral efforts described.

### **[NEED DEVELOPING COUNTRY EXAMPLES]**

#### ***1.7.5 Actions Taken at Other Levels of Government***

In addition to nation plans, in many countries, state and local governments are generating programs to confront climate change issues. Countries also combine to work together to develop responses. The European Union has been developing policies in tandem. [place holder for written discussion of supranational, regional, or local actions]

## 1.8 SUSTAINABLE DEVELOPMENT

### 1.8.1 *What is Sustainable Development?*

Different observers have defined sustainable development in different ways. The Brundtland Commission (1987) offered this interpretation:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs ... Living standards that go beyond the basic minimum are sustainable only if consumption standards everywhere have regard for long-term sustainability.

The Interamerican Development Bank (date) suggested this definition:

Development that distributes the benefits of economic progress more equitably, protects both local and global environments for future generations, and truly improves the quality of life.

Among economists, Robert Solow makes the case that sustainable development is

an injunction to preserve productive capacity for the indefinite future. That is compatible with use of nonrenewable resources only if society as a whole replaces used-up resources with something else.

From the point of view of the social sciences, sustainable development requires that future generations be able to achieve a standard of living at least equal to that of the current generation. Thus sustainable development refers more to intergenerational equity than to economic efficiency.

Several rules may define a sustainable development path. One rule would ensure constant levels of capital stocks over time, where capital stock is defined broadly to include man-made capital (such as roads and factories), human capital (an educated population), and natural capital (such as forests). The capital stock in turn depends on the rate of saving, broadly defined, and the rate of technical change.

The global challenge of sustainable development is to meet this criterion in a world where population will increase by 50% or more by the middle of the next century. Thus the correct measure of success is per capita welfare, not aggregate welfare, implying a resource base that meets the needs of far more people than are alive today.

### 1.8.2 *The Need for a Broader Definition of GDP.*

In setting targets for sustainable development, the current system of national accounts has been considered too narrow on several grounds (Daly and Cobb, 1989; Sterrer, 1993):

1) Defects in reflecting current welfare. GDP and similar measures indicate changes only in

traded goods and services, omitting many activities important in the measurement of human welfare.

2) Inadequacy of measuring environment and natural resources. National income accounts do not reflect possible deterioration of a nation's resource base. Economic activity measured by GDP may not represent a sustainable path over the long run.

3) Incomplete measure of output. Standard national income accounts overlook the production of some undesirable outputs, such as pollution; for example, increased expenditures on medical services resulting from increased pollution levels are now counted as a gain in GDP. Further, while conventional the standard accounts properly include depreciation of certain forms of capital (plant and equipment, buildings), they neglect depreciation of natural resources and environmental capital.

### **1.8.3 *Modifying National Accounts.***

Four approaches are commonly used to calculate changes in the natural environment (**Peskin and Lutz, 1990**):

- a) The environmental expenditure approach, used recently in the United States, identifies pollution abatement and other expenditures but leave conventional GDP unchanged;
- b) The physical accounting approach, used in Norway and France, uses physical units of measurement to account for flows and stocks of resources;
- c) The depreciation approach adjusts gross and net product by subtracting out the value of natural resource depletion (Repetto 1989); and
- d) The comprehensive approach uses both physical measures and value (**Statistical Office of the United Nations, 1992**).

#### **1.8.3.1 *Value of revised national accounts***

Currently it is very difficult for most policy makers to find consistent economic data that incorporates the value of the environment. Efforts to develop better information on the value of scarce natural resources, the impact of pollution on the economy, or the benefit of environmental protection will be of great value to policy makers. Reliable consistent data can help decision makers by clearly quantifying the trade-offs from any policy proposal.

#### **1.8.3.2 *United States natural resource and environment accounts***

Some nations are already modifying their national income accounts using these approaches. The United States, for example, has been redesigning its economic accounts to include natural resource accounting, following the guidelines of the International System of National Accounts (SNA) and their satellite system for integrated environmental and economic accounting (SEEA). These efforts seek to produce an integrated set of current and capital accounts, sector by sector. The U.S. Department of Commerce's Bureau of Economic Analysis plans to develop these accounts in three related phases.

The first phase, completed in April 1994, focuses on producing prototype estimates of the economic value of nonrenewable natural resources and developing a framework for natural

resource accounts for the United States. The work on nonrenewable natural resources concentrates on mineral resources - oil, gas, coal metals and other minerals with a scarcity value. Following the SNA recommendations the effort focuses on proved reserves, the valuation is at market values, and the resources are treated symmetrically with fixed capital. These prototype measures of resource stocks and flows will supplement the national wealth accounts and national income and product accounts. In addition, these estimates will provide the basis for a measure of GDP that is adjusted for depletion of these natural resource assets. This exercise will also explore alternative methods of resource accounting.

Also part of the first phase is an effort to take these new nonrenewable resource estimates and incorporate them into the broader SEEA framework. The SEEA's purpose is to expand upon and compliment the SNA by highlighting and quantifying the interaction of the environment and the economy. For example the SEEA will attempt to capture the effect of production on environmental quality or the effect of environmental protection and restoration expenditures on the environment.

The second phase will involve extending the accounts for nonrenewable natural resources to renewable natural resources. Estimates for renewable resources like forests, water aquifers and fish stocks, are more difficult to develop because data sources and concepts are less well developed. During this phase work will also be done to improve the initial estimates of nonrenewable assets.

Building on the work of its two earlier phases, the U.S. will look at a broader range of environmental assets in its third phase. This phase will focus trying to quantify the degradation of clean water and air and the valuation of recreational assets such as lakes and national forests.

While there is much work to be done to generate the complete set of new accounts they will prove invaluable to policy makers. The fully developed accounts will allow decision makers to make trade offs with a view of both natural and man-made capital, consistently covered and appropriately valued.

#### 1.8.3.2 *Human Development Index*

As an alternative index intended to be more closely related to human welfare, the UN Development Program has proposed the human development index or HDI (UNDP, 1990). The HDI gives a composite measure of human development by combining three key indicators: longevity (measured by life expectancy at birth), education (measured by adult literacy and mean years of schooling), and income (real GDP per capita adjusted for purchasing power). Although the HDI is not directly related to global environmental issues, both global warming and abatement policies may affect it.

HDI is one measure that may give policy makers better information about how the environment impacts society. Each of the factors in the index can be influenced by the environment. A good example is the role that pollution and other environmental hazards can

have on life expectancy.

#### **1.8.4 *Implications of Sustainable Development for Developing Countries.***

The poorer nations will experience the largest increase in population, and the greatest pressure to consume their resource base. At the same time, they often cannot command the investment to replace depleted resources, nor do they have the technological resources to offset the loss of their capital stock. These obstacles will make it difficult for many developing countries to achieve a sustainable development path.

#### **1.8.5 *Sustainable Development and the Risks of Climate Change.***

Climate change imposes special demands on the ability to achieve sustainable development. A rapidly or unpredictably changing climate can disturb orderly economic development plans. Shifting agricultural production regions, for example, can result in the diversion of capital resources that would have been available for other more productive uses. The costs of mitigation and adaptation may take resources from necessary consumption, and may crowd out investment that would make sustainable development possible. Responding to climate change increases the uncertainty and the cost of achieving sustainable development. At the same time, sustainable development does not mean that all resource stocks remain unchanged; an increase in capital stock can substitute for a decrease in other resources.

Developing countries face particular burdens; their development is likely to be the most affected by the risks of climate change. Many potential environmental consequences--such as rising sea levels--will particularly affect developing countries simply because of their location. At the same time, they often lack the financial and technical resources to respond. Further, many developing countries rely heavily on fossil fuels either for export earnings or for energy consumption, and thus would feel the impact of fossil fuel restrictions. Developing countries can move closer to a sustainable development path by rationalizing resource pricing and otherwise removing barriers to markets. At the same time, these improvements are not likely to offset the increased costs of slower development.

##### **1.8.5.1 *Population change.***

Increasing population increases the demand on resources, including energy. The world's population is growing at the rate of 1.7% per year, down from its peak of 2.1% per year in the late 1960's (**World Bank, 1992**). Under the World Bank's base case projection, world population would stabilize at 12.5 billion sometime after 2050, more than double the current total, with 95% of the increase in developing countries. Population growth is expected to contribute to pollution of water, air, soils, in addition to problems of deforestation, and loss of biodiversity.

Disagreement exists over the future trend in population growth in developing countries. Past declines have shown that less developed countries are not going through the classical demographic transition that took place in industrialized countries over the last century. The World Bank, for example, in its 1992 World Development Report stated "declining fertility rates associated with these projections should not be taken for granted. They are

rapid historical context, they imply substantial progress in education and income opportunities for women and they will require a doubling in real terms of annual expenditure on family planning programs from \$4 billion (US) to \$8 billion (US) during the 1990's."

This view is supported by Bongaarts (1994) who calls for even greater extension of family planning programs beyond the traditional contraceptive information, services, and supplies typically provided.

A study by Robey *et al.* (1993) examines the decline in fertility rates in many developing countries. They find that throughout the developing world, birth rates have declined by one third since the mid-1960s: women formerly had six children on average, but today they have four. They cite evidence that birth rates in the developing world have fallen even in the absence of improved living conditions. The decrease has also proceeded with remarkable speed. Developing countries appear to have benefited from the growing influence and scope of family-planning programs, from new contraceptive technologies and from the educational power of mass media.

A recent study examined total fertility rate for different countries as a function of their commercial energy consumption (Goldemberg, 1994) as shown in Figure 1, which indicates the dramatic drop in total fertility rates for energy consumption per capita higher than 2 kw/capita.

It is not energy consumption "per se" that leads to a decrease in total fertility rate, but the services provided by energy such as lighting, cooking, space conditioning, motive power, etc. which improve living standards leading in turn to better education, medical services and access to information. Therefore energy consumption is linked to population growth and needs to be considered in policy choice for actions to reduce greenhouse gases.

#### 1.8.5.2 *Energy use.*

Population pressures and economic development will result in greater energy use, which in turn will increase CO<sub>2</sub> emissions. The consumption of commercial energy in developing countries is rising rapidly and will soon dominate growth in energy consumption--and thus CO<sub>2</sub> emissions--worldwide. In 1985, LDCs including China contributed 19% of worldwide carbon emissions. By 2020, LDCs are expected to contribute ---% of a larger total (World Bank, 1992).

Some researchers have proposed that LDCs address economic growth and environmental concerns simultaneously by "leapfrogging" earlier development paths. By adopting modern energy sources (electricity, renewable liquid and gaseous fuels, etc.), and new energy-efficient technologies, LDCs would decouple energy use from economic growth, just as the industrialized countries are doing by the shift to services, and to less energy-intensive materials. Whether this is a practical development path remains to be seen.

#### 1.8.5.3 *Deforestation.*

Developing countries also contribute to net increases of greenhouse gas emissions by deforestation. In recent years, deforestation, nearly all from developing countries, contributed about 24% of carbon dioxide emissions. [J. Goldemberg is this correct ??]

#### 1.8.5.4 *Afforestation.*

Afforestation of open land is one of the most promising options for the sequestration of CO<sub>2</sub> from the atmosphere. Even though afforestation's contribution to carbon absorption is ultimately limited by land area and growth rates, it could postpone the increase of CO<sub>2</sub> concentration as well as check erosion and land degradation in general in many areas of the developing world.

Significant variation exists presently among the many cost studies. However, it is clear that significant opportunities exist for cost-effective reductions in net carbon emissions via sequestration. Table 1 compares the results of several cost studies of carbon sequestration, organized by forest type .

While some of the variation among these results can be explained by variations in methodology, much of the difference among the studies stems from differences in underlying assumptions. Among the key differences in assumptions that contribute to the considerable uncertainty in the precise costs and potential role for sequestration of carbon are: land, establishment, and maintenance costs; carbon uptake rates; transactions costs; and the choice of discount rates.

Even with the broad range of uncertainty that presently exists, there appears to be significant opportunities for carbon sequestration as an element of a carbon emissions reduction policy. It is likely that afforestation could contribute as much as 10<sup>9</sup> tonnes to a reduction in global net annual carbon emissions. When forest management and agroforestry practices and biomass energy technologies are included in the technological response options, the potential contribution of managed forest ecosystems rises to above 2X10<sup>9</sup> per year (Dixon et al, 1991; Hall et al., 1993; Dixon et al., 1994).

Afforestation on a large scale also opens up the possibility of greater diversification in electricity generation. Recent technological advances in wood gasification coupled with aeroderivative gas turbines increases the potential for the replacement of fossil fuels by biomass in power generation, depending on various economic factors and local circumstances.

**TABLE 2**  
**Potential for Carbon Sequestration through Afforestation**

|                                                            | Global             | Tropical                       | Temperate        |                              |                                     |                                   |
|------------------------------------------------------------|--------------------|--------------------------------|------------------|------------------------------|-------------------------------------|-----------------------------------|
|                                                            | Nordhaus<br>(1992) | Dixon, <i>et al.</i><br>(1991) | Jarvis<br>(1989) | Hall <i>et al.</i><br>(1993) | Van Kooten,<br><i>et al.</i> (1992) | Richards,<br><i>et al.</i> (1993) |
| Area suitable for<br>afforestation<br>(10 <sup>6</sup> ha) | 510                | 593                            | 370              | 758                          | 9 (Canada)                          | 102 (U.S.)                        |
| Removal rate<br>(tonnes C/ha/year)                         | 0.8-1.6            | 0.3-2.5                        | 2.7              | 5                            | 0.6-0.8                             | 0.0-4.3                           |
| Total removal rate<br>(10 <sup>6</sup> tonnes/yr)          | 280                |                                | 1000             | 3790                         | 6                                   | 540                               |
| Costs of removal<br>(US\$/tonnes C)                        | 42-114             | 5-8                            |                  | 28                           | 66-187                              | 9-66                              |

#### 1.8.5.4 *Poverty.*

Although substantial progress has been made in the last 25 years, more than one-fifth of humanity still live in acute poverty. In the late 1980s, many regions saw earlier gains slowed or even, as in Africa, reversed. World Bank analysts expect a decline in the incidence of poverty over the next decade in Latin America, Asia, and Eastern Europe, but an increase in poverty in Africa (**World Bank, 1992**). The recently demonstrated link between poverty and pollution has led some to call for measures to increase the pace of development as an approach to the issue of environmental quality in the LDCs.

## 1.9 WHAT IS KNOWN ABOUT CLIMATE CHANGE?

Social scientists are in general agreement on some points of climate change analysis. This section lists those points on which there is general consensus.

- *Value of information.*  
Better information leads to better decisions. Because of limits to current knowledge and the high cost of being wrong in either direction, the value of better information on climate change is likely to be great.
- *Importance of insurance and hedging*  
Insurance against greenhouse-related costs may take several forms, depending on the probability of the adverse outcome, the loss in value of the outcome, and the cost of insurance. An optimal hedging strategy will depend on the uncertainty surrounding current knowledge, and the likelihood and timing of new supply, conservation, and adaptation strategies.
- *Importance of flexibility in timing*  
The timing, predictability, and flexibility of policies introduced to reduce greenhouse gas emissions will significantly affect the cost of those policies. Capital stocks in the energy using and energy producing sectors of the economy change only slowly over time, while new technologies may take decades to come into common use. Consequently, the transition to a less carbon intensive economic regime can be less costly if the transition is predictable and made gradually. In addition, the transition will be less costly if it is accomplished using flexible policy instruments, including carbon taxes and tradable permits.
- *Carbon taxes, tradable emission permits*  
Carbon taxes or tradable permits can reduce greenhouse emissions at a lower cost than command-and-control regulations, because taxes and permits take advantage of information in the hands of producers, and of differences in control costs.
- *Market structure reform*  
Many reforms that remove market distortions, including removing subsidies to coal producers and to energy consumers, will reduce greenhouse emissions.
- *Irreversibilities.*  
In the presence of irreversibilities, uncertainties, and learning, an optimal policy is likely to be cautious in the sense that irreversible commitments are postponed, pending the acquisition of better information.
- *Portfolio of responses.*  
In the presence of uncertainty, and with some statistical independence among the uncertainties, policy makers can reduce risk by adopting a portfolio of responses rather than attempting to settle on one optimal policy. A balanced portfolio of responses

includes not only policies to reduce current emissions, but also funding to expand research to reduce uncertainties, and to lower the costs of future adaptation and mitigation.

- *Sequential dynamic decision making.*

Decisions will be made in the 1990s in the face of uncertainties about damages and long-run control costs that will not be resolved for decades. Major uncertainties will be resolved, and decisions made, during each of the next several decades. The optimal decision today depends in part on how future uncertainties will be resolved. The techniques of probabilistic analysis may be combined with dynamic optimization to incorporate results of future research into today's decisions.

- *Importance of extreme events*

Many of the costs of climate change are likely to stem from extreme climatic events: days of extreme heat or drought, increased severity of storms, etc. Conversely, some of the benefits will result from a reduction in extreme events, for example, fewer days of killer frosts in some cold regions.

- *Low-cost energy efficiency improvements*

A reservoir of low-cost energy efficiency improvements remains to be exploited, although the size of the reservoir is disputed.

- *Joint implementation*

Cooperative efforts between nations to reduce greenhouse gas emissions can reduce total emissions and total costs at less cost than if each nation acts separately.

- *Large uncertainties in computed results*

Economic models of greenhouse emission mitigation show wide variation among models, although the differences narrow when the models are run on a comparable basis. In the long run, their results will depend critically on GDP growth, etc., which cannot be predicted with any accuracy. As a result, economic models are likely to vary at least as much as physical science models, on which they often depend.

- *Importance of flexibility, time path*

The cost to the economy of reducing greenhouse emissions will depend on the flexibility allowed in reaching an emission reduction path.

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