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

THE CHAIRMAN

Statement before the House Commerce Subcommittee on Energy and Power

Dr. Janet Yellen

Chair, Council of Economic Advisers

Tuesday, July 15, 1997

Good afternoon, Mr. Chairman and members of the Subcommittee. I appreciate the opportunity to discuss with you today the economics of global climate change.

Introduction

In his speech to the United Nations Special Session on Environment and Development in June, President Clinton emphasized that the risks posed by global climate change are real and that sensible preventive steps are justified. This assessment accords with the views of the more than 2300 economists, including 8 Nobel laureates, who signed a statement supporting measures to reduce the threat of climate change. The economists endorsed the conclusions from last year's report by the Intergovernmental Panel on Climate Change (IPCC), which said that governments should take steps to reduce the threat of damage from global warming, and went on to argue that market-based policies can slow climate change without harming the American economy.

At this time the Administration has not settled on a particular set of new policies to reduce greenhouse gas emissions. Instead, the President indicated in his U.N. speech that he intends to engage in a discussion with all interested parties about the problems posed by

greenhouse gas accumulations and the costs and benefits of corrective action. To this end, the President will hold a White House conference on climate change later this year, and Members of his Cabinet and other senior Administration officials will meet with Members of Congress, scientific and economic experts, environmentalists, local government officials, and business and labor leaders on a regular basis over the next several months to discuss issues related to climate change. This process is intended to inform the Administration's decision-making process, which will culminate in a U.S. policy position in the international negotiations in Kyoto in December of this year.

An important step in this -- and any -- policy process is determining the impact it will have on the American economy. President Clinton's top priority, since his first days in office, has been revitalizing the U.S. economy, creating jobs and investing in people and technology to enhance long-term growth. And, we have made tremendous progress. The President is not going to jeopardize that progress. Any policy he ultimately endorses on climate change will be informed by his commitment to sustaining a healthy and robust economy.

In my testimony today, I would like to describe some of the principal lessons that emerge from the voluminous literature, much of it relatively recent, on the economic impacts of policies to address global climate change.

Underlying Uncertainties

Before I begin my discussion of the economic literature, I would like first to acknowledge the uncertainties associated with estimating both the costs and benefits of reducing greenhouse gas emissions. To provide some perspective: as you all know, it is difficult to gauge exactly what impact the balanced budget agreement will have on the U.S. economy's growth rate, levels of employment, interest rates and consumption over the next five years. But with global climate change, it is orders of magnitude more difficult to gauge the effects on the economy: we are concerned with not just the next five years and not just the American economy, but, rather, we are dealing with economic and physical processes that operate globally and over decades, if not centuries.

Although a great many scientists believe that global climate change is already underway, the more serious potential damages associated with increasing concentrations of greenhouse gases are not predicted to occur for decades. This means that the benefits of climate protection are very difficult to quantify. And, while the potential costs of reducing greenhouse gas emissions may be more immediate, they too, as I will discuss below, are difficult to predict with any certainty. Many unanswered questions exist about the biophysical systems, potential thresholds, and economic impacts. In short, if anybody tells you that he or she has the definitive answer as to the costs and benefits of particular climate change policies, I would suggest that you raise your collective eyebrows.

Lessons from the Economic Literature

Let me now turn to the economic literature and try to summarize what I think we know so far about this difficult topic. Most economists have not addressed the benefits of climate protection, but rather have focused on the costs associated with alternative paths for reducing greenhouse gas emissions. The economic literature includes estimates using many different models to evaluate numerous alternative emission reduction strategies. In fact, because there are so many different models, economists initially faced difficulties in comparing results: they could not sort out the extent to which differences in results stemmed from differences in models and assumptions versus differences in baseline emission paths and policies. To solve this problem, thereby enabling meaningful comparisons, many economists have calibrated the various models by performing a standardized simulation. Specifically, they have assessed the consequences of stabilizing greenhouse gas emissions at 1990 levels by 2010 or 2020.

Within the Administration, a staff level working group -- the Interagency Analysis Team (IAT) -- has attempted to estimate some of the economic implications of climate change policies. They took the emissions scenario most often used in academic literature -- that is, stabilizing emissions at 1990 levels by 2010 -- as the starting point for their own analysis. I would emphasize that this scenario is not Administration policy; instead, it was picked to make comparisons with other models easier. The staff group employed 3 different models -- the DRI model, the Second Generation Model (SGM) and Markal-Macro model, all commonly available in the public sphere. In running these models, the staff adopted a common baseline and, to the maximum extent possible, similar economic assumptions. This modeling effort produced some

useful lessons, but as we found from the peer reviewers' comments, it also suffered from some serious shortcomings. Both the lessons and the shortcomings point to one clear conclusion: the effort to develop a model or set of models that can give us a definitive answer as to the economic impacts of a given climate change policy is futile. Rather, we are left with a set of parameters and relationships that influence estimates of the impacts. In my view, it is more productive to employ a broad set of economic tools to analyze policy options than to seek to develop a single definitive model.

I understand that a draft of the staff analysis was given to the Subcommittee this morning, along with the reviewers' comments. I would be happy to answer any questions you may have about this modeling effort.

The Lessons. Modeling efforts both inside and outside the Administration clearly indicate that economic analysis can do no more than estimate a range of potential impacts from particular policies and highlight how outcomes depend on underlying assumptions about how the economy works and the ways in which policy is implemented. However, the economics literature on climate change does point to several important lessons:

How the economy works. First, the magnitude of the costs of reducing greenhouse gas emissions in the various models depends crucially on a number of key assumptions about how the economy works. For instance:

- If firms in the economy can shift from high-carbon to low-carbon energy sources quickly, the costs of climate protection will be lower.
- If the economy has significant opportunities, even now, to employ energy-saving technology at low costs, the costs of climate protection will be lower.
- If technological change occurs at a rapid rate, or is highly responsive to increases in the price of carbon emissions, the costs of climate protection will be reduced.
- If the Federal Reserve pursues a monetary policy oriented toward keeping the economy at full employment, transitional output costs will be lower.

In short, the greater the substitution possibilities and the faster the economy can adapt, the lower the costs.

How the plan is implemented. Second, costs depend critically on how emission reduction policies are implemented. It boils down to this: if we do it dumb, it could cost a lot, but if we do it smart, it will cost much less and indeed could produce net benefits in the long run. The over 2300 signatories of the economists' statement argued that any global climate change policy should be rely on market-based mechanisms. Such mechanisms allow for flexibility in both the timing and location of emission reductions, thereby minimizing the costs to the U.S. economy. The economists concluded that "there are policy options that would slow climate change without harming American living standards, and these measures may in fact improve U.S. productivity in the longer run."

- The speed at which emissions reductions are required can have large effects on the estimated costs. It is important to allow sufficient lead-time for orderly investment in new equipment and technology. Alternatively, if emission reduction requirements are too far off in the future, the incentives to adopt energy efficient technologies are weakened because people may not view the policy as credible.
- A "cap and trade" system in which emission permits are issued and then traded among firms can substantially reduce the cost of meeting an emissions target by creating incentives for emissions to be reduced by those firms and in those activities where costs are lowest.
- International emission permit trading substantially lowers costs by applying the same cost-minimizing principle globally.
- So-called "banking" and "borrowing" of permits increases flexibility and lowers costs by allowing firms to change the timing of their emission reductions.
- Joint implementation, whereby US firms would receive credit for undertaking emission reductions in countries with low abatement costs, would also lower the domestic burden.

An additional aspect of implementation that profoundly affects the costs of reducing emissions concerns "revenue recycling." In many model simulations, emissions are reduced by using various market mechanisms. For many of these scenarios, the Federal government realizes an increase in revenues. Economic growth can receive a

long-term boost if these revenues are used to reduce distortionary taxes that diminish the incentives to invest, save or work, or if the revenues are channeled into deficit reduction, thereby lowering interest rates and boosting investment. In fact, in some models and scenarios, emissions reduction generates a net economic benefit when the revenues are recycled in a growth-promoting fashion.

Which countries participate. The third lesson that emerges from a study of the economics of climate protection is that developing, as well as developed, countries must be part of the process. While developed countries are responsible for most of the greenhouse gas currently in the atmosphere, developing countries are starting to catch up. By 2040, the largest fraction of emissions is estimated to come from developing countries. Thus, any comprehensive plan to deal with this global problem must include a mechanism to bring developing countries into the process.

The timetable for the inclusion of developing countries is also important. The sooner that developing countries face incentives to move away from carbon intensive energy sources, the less likely it is that they will become dependent on those types of fuels to spur their economic growth. In short, global problems require global solutions. We must find the technologies and solutions to lead the way.

Conclusion

Let me conclude. Policies to promote economic growth, create jobs, and improve the living standards and opportunities of all Americans have been and always will remain the top priority of the President and his Administration. In his remarks to the Business Roundtable on global climate change, the President said "[l]et's find a way to preserve the environment, to meet our international responsibilities, to meet our responsibilities to our children, and grow the economy at the same time."

Some of the key economic lessons we have learned that will help us achieve the President's goal include:

- Inherent uncertainty dictates that models should be expected to generate only a range of economic impacts, not definitive answers.
- Key assumptions about how the economy works directly influence the estimated costs of climate protection.
- Implementation of any policy needs to be market-based and flexible over time and space to achieve the lowest cost reductions.
- All nations, both developed and developing, need to participate.

Thank you. I would be happy to answer any questions you may have.

Testimony C

THE WHITE HOUSE

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SENDER: **TODD STERN**

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PAGES: 9

DATE: Sept. 15, 1997

MESSAGE: Questions for Janet Yellen. From Committee on Commerce.

U.S. House of Representatives
Committee on Commerce
Room 2125, Rayburn House Office Building
Washington, DC 20515–6115

August 22, 1997

Todd Stern

The Honorable Janet Yellen
Chair
Council of Economic Advisors
Old Executive Office Building
Washington, D.C. 20502

Dear Ms. Yellen:

On July 15, 1997, you presented the Administration's views on the economic and environment impact of the proposed international global climate change agreement before the Energy and Power Subcommittee. On behalf and the members of the Subcommittee, I thank you for your informative testimony. The hearing was indeed enlightening.

With the conclusion of the eighth meeting of the Ad Hoc Group on the Berlin Mandate, I see significant benefit to a round of follow-up questions to clarify, for the record, some of the issues that were raised during your testimony and the question and answer session that followed.

Attached is a list of questions for you to answer on behalf of the Administration. I ask that you work with the other relevant departments and agencies in developing responses and providing the relevant documentation where requested. Your responses will be entered into the record in the same manner as your original testimony. Your responses would be appreciated on or before September 22, 1997. If you have any questions, please call Cathy Van Way at (202) 225-2927.

Thank you for your continued attention and assistance to the matter.

Sincerely,

Dan Schaefer
Chairman
Energy and Power Subcommittee

Attachment

cc: The Honorable Tom Bliley, Chairman
The Honorable John Dingell, Ranking Member
The Honorable Ralph Hall, Ranking Member
Subcommittee on Energy and Power

10. Is the paper prepared by the IAT both an analysis and assessment? How does it relate to the "analysis and assessment" referred to in Paragraph 4 of the Berlin Mandate? Has the Ad Hoc Group on the Berlin Mandate provided an analysis and assessment as required by the Berlin Mandate?

11. The IAT draft states that the central policy modeled for the analysis "is aimed at reducing carbon and other greenhouse gas emissions by stabilizing them at 1990 levels" and that policy would be "announced in 2000 and its restrictions are phased in over a ten year period, so that the policy would take full effect in 2010." Reports in the media after the Denver Summit that President Clinton attended also referenced this date of 2010. In light of EIA's projection of emissions 22% above 1990 levels by 2010, is the Administration considering a target and timetable that calls for stabilization at 1990 levels by 2010?

12. The Administration frequently cites the 2000 economists who say they support controlling greenhouse gases. Their statement supports as the mechanism either carbon taxes or emission permits. In the past, the Administration has said it opposes the use of taxes. Is that still the Administration's position?

13. The IAT draft explains that these emission reductions to achieve stabilization would be through "issuing tradable permits at the earliest point of energy production or when imported into the U.S." and that the permits "are initially auctioned in a way that is revenue neutral: i.e., all revenues generated would be recycled through the economy." Would these revenues be deposited in the treasury as miscellaneous receipts under the Economy Acts? Would they then have to be recycled through changes in the tax laws or by appropriation? How would they be recycled?

14. Does the Administration believe that permit auctions are the equivalent of a new tax? If not, please explain.

15. The IAT draft states that "among fuels, demand for coal bears the brunt of greenhouse gas stabilization." What is the impact on the U.S. economy as a whole and on the relevant coal regions of this policy towards coal? What will be the job impact? Is the Administration adopting an anti-coal policy? How is this policy consistent with President's Clinton 1995 reply to Mr. Dingell that the U.S. will not agree to any protocol that harms our economy and jobs or our competitiveness?

<u>Kyoto Agreement</u>

16. How long after December 1997 does the Administration think it will take to obtain Senate advice and consent of any Kyoto agreement, to ratify that agreement, and to enact implementing legislation?

17. Which Agency or Department would be responsible for implementing the provisions of any agreement reached in Kyoto, including provision relating to joint implementation, emissions trading, and advancing Article 4.1?

SUBCOMMITTEE ON ENERGY AND POWER
HEARING ON GLOBAL CLIMATE CHANGE
FOLLOW-UP QUESTIONS

Interagency Analytical Team Report

1. Please identify each member of the Interagency Analytical Team (IAT) from the date of its inception to the present time, any other participants inside or outside the Administration, and specify their responsibilities.

2. When was the IAT formed and what were the IAT's instructions? Please provide any documentation regarding the formation of the IAT and its mission, responsibilities, membership or assignments.

3. Please indicate the total costs of the IAT's efforts and the share paid annually by each Department or Agency that was involved and please identify the source of the funds within each Department or Agency.

4. Is the IAT still in existence? If so, what are its current responsibilities?

5. Please provide a copy of all drafts of the IAT report in addition to the May 16 and 30, 1997 drafts, both earlier and later.

6. Please explain how the peer reviewers were selected? What instructions were those peer reviewers given? Please provide copies of any correspondence or instructions that were sent to the peer reviewers.

7. If the IAT effort is in fact a "failed" project as indicated in Administration testimony at the Subcommittee hearing how will the Administration determine the appropriate level of future international climate change commitments for Kyoto and later?

8. As late as last May when Dr. Ehrlich and others in the Administration held briefings on the then draft analysis and assessment there was no hint that the Administration considered this effort a failure and the models to be unreliable. What occurred since May that caused the Administration to apparently reach a different conclusion from that of Dr. Ehrlich?

9. The IAT draft analysis referred to three scenarios which resulted in costs of future climate commitments of approximately $200, $100 or $50 per ton carbon tax equivalent. Has the Administration concluded that a $200 per ton carbon tax equivalent cost will not harm the U.S. economy, jobs, and global competitiveness? Has the Administration concluded that a $100 per ton carbon tax equivalent cost will not harm the U.S. economy, jobs, and global competitiveness? Has the Administration concluded that a $50 per ton carbon tax equivalent cost will not harm the U.S. economy, jobs, and global competitiveness. Please provide the basis for any of the above conclusions. If the Administration does not support any of the above costs, what analysis or other information does the Administration intend to rely on to support a different amount?

18. What consideration has been given or plans made regarding passage of legislation necessary to implement any agreement reached in Kyoto?

U.S. Draft Protocol

19. Article 17.4 of the Framework Convention on Climate Change (FCCC) specifies that only "Parties to the Convention may be Parties to a protocol." However, there is no assurance that all or even a majority of the 167 Parties to the FCCC will deposit instruments of ratification, acceptance, approval or accession to any protocol adopted by the Parties by consensus or otherwise in Kyoto. What assurances does the U.S. now have that most, if not all, developing country Parties to the FCCC will become Parties to a Kyoto protocol? Why is it in the U.S. interest to agree, without such assurances, to a protocol that proposes to set legally binding post-2000 targets and timetables for Annex I Parties only and also imposes on the U.S. new and legally binding commitments to advance implementation of Article 4.1. of the FCCC, such as those prescribed in paragraph 1, 2, 3, and 4 of Article 5 of the U.S. draft protocol?

20. In a July 18, 1994 letter to the then House Committee on Energy and Commerce, [the State Department] said:

> We agree that there are substantial commitments beyond 2000 for all parties to the Framework Convention under Article 4. Article 4.1 (applicable to both developed and developing countries) contains commitments that are not limited by any specific timetable.

a) Is there any evidence to date that the U.S. is not abiding by these Article 4.1 commitments? If there is none, why should the U.S. voluntarily agree to reaffirm, as required by Article 5.1 of the June draft, to what the U.S. already agreed to when it ratified the FCCC in 1992?

b) Is the U.S. asserting that other Annex I Parties are not abiding by such commitments? If so, please identify those Parties.

21. Paragraph 2 of Article 5 of the U.S. draft Protocol mandates each Party to "strengthen its legal and institutional framework to advance implementation" of Article 4.1 commitments. What "framework" does the Administration have in mind? Does this suggest a new Federal or international agency or program? Would this be done through new legislation? If not, how would it be achieved in the U.S.?

22. Article 5.3 requires that each Party take "measures to facilitate investment in climate-friendly technologies." What "measures" does the Administration contemplate? How would they be implemented in the U.S.? What are their regulatory and budgetary implementations?

23. Article 16 of the draft provides that the Parties "shall adopt, by [2005], binding provisions so that all Parties have quantitative greenhouse gas emissions obligations and so that there

is a mechanism for automatic application of progressive greenhouse gas emissions obligations to Parties, based upon agreed criteria."

a) Does this mean that there could be a second protocol or another legal instrument by [2005] which is only 7 years after the December meeting in Kyoto?

b) Do the words "all Parties" in this Article mean that only the "Parties" to the U.S. draft protocol would be required to "adopt" by 2005 such an instrument? Unless developing country Parties to the FCCC, such as China, India and Brazil, become Parties to the Kyoto instrument (as proposed by the U.S.) prior to [2005], how does this Article address the issue of greenhouse gas emission growth by all non-Annex I Parties?

c) Could such a new instrument adopted by [2005] impose new and additional obligations on the U.S. beyond those proposed to be adopted in Kyoto? Why is that possibility a good result for the U.S. economy, trade, and competitiveness?

d) What "mechanism for automatic application of progressive greenhouse gas emissions obligations" does the Administration contemplate by this proposal? What are its implications for the U.S., including its sovereignty?

24. Article 16.1 of the Convention provides that "annexes shall be restricted to lists, forms, and any other material of a descriptive nature that is of a scientific, technical, procedural or administrative character." The U.S. draft protocol states, that it may not be "appropriate" to adopt the Article 16.1 Convention example. Please explain why. Does the U.S. support annexes that would be substantive and mandatory?

25. Article 9 of the U.S. draft provides that Parties "shall cooperate" in establishing a "long-term goal" regarding concentrations of gases. Article 10 calls for meetings at "regular intervals" to, among other things, "periodically review the adequacy" of the Protocol and Article 8 calls for periodic review of the Protocol and guidelines "in light of evolving scientific knowledge related to climate change." Article 2 already suggests a minimum of two budget periods. Article 16 tells the Parties to adopt "binding provisions" by [2005] for progressive "obligations." Does the State Department contemplate over the next several decades a continuing process of meetings of both the Protocol and Convention Parties annually and a series of IPCC assessments, special reports, and technical papers, leading to a series of protocols or other legal instruments that are likely to have significant economic impacts on the Parties and their people? Why is there a need for such frequent meetings and reviews?

26. The Global Climate Coalition sent a letter to the Department of State on February 14, 1997 raising a number of questions about the January 17, 1997 version of the U.S. draft protocol, particularly in regards to trading. The Administration has not yet responded to those questions. Please respond to them as part of your reply to this inquiry.

EU Bubble

27. The EU proposal made recently in Denver was developed last March as an EU "negotiating position for the ongoing negotiations on the Berlin Mandate" and it includes burden-sharing of a 10% reduction among EU members of the "overall emission reduction objective by the Community as a whole". This appears to be a form of differentiation, a concept the U.S. is not supporting. The existing FCCC bubble applicable to the EU presumably only covers policies and measures and, when adopted, it only covered the 12 Parties that were members of the EU in 1992. Does the U.S. understand that the EU is seeking, by its submissions and discussion with the U.S. delegation, to extend a form of the FCCC bubble to a protocol and another legal instrument that may be adopted in Kyoto, to expand the bubble to cover any target and timetable or financial obligations and not just policies and measures, and to expand the bubble to include all present and future members of the EU, such as countries from Central and Eastern Europe? Why is such an expanded bubble in the economic and competitive interests of the U.S.?

28. What is the potential impact of such an expanded EU bubble on the U.S. proposal for international emissions trading? Would it ensure that the EU would get the benefit of any emissions deficit derived from such Central and Eastern European Members and deprive the U.S., Japan, Australia and Canada of that deficit? Would the U.S. then have to rely primarily on Russia's emissions deficit in order to derive any of the benefits of trading?

29. Article 22.3 of the FCCC requires that regional economic integration organizations must declare the "extent of their competence" with regard to obligations under the FCCC. Does the U.S. believe that the EU has the competence to carry out legally binding targets and timetables and to enforce any differentiated targets for its members if they fail to achieve them?

30. The State Department's September 9, 1996 reply to the Committee stated that the U.S. did not agree to an "EU Bubble in Berlin" and that the U.S. delegation "successfully opposed including language in the Berlin Mandate which might have suggested that any country or group of countries could "bubble" in the post-2000 period." The reply then said:

> Clearly, the question of "bubbling" with respect to post-2000 commitments is complex, and one that will be closely scrutinized and carefully considered as negotiations progress. The Administration has consistently and continuously consulted with Congress, as well as with U.S. industry and U.S. NGOs, on all aspects of the negotiations concerning post-2000 commitments and will continue to do so.

The Administration has not yet held meaningful discussions with this Committee on the issue of the EU bubbling to "meet and target and timetables," its implications for the U.S., its merits, or its complexities. Given the fact that negotiations are just approaching a conclusion in Bonn and Kyoto, when do you plan to consult us on this aspect of the negotiations?

31. Since 1992, the composition of the only "regional economic integration organization," namely the EU, has grown from 12 to 15 members and several other countries want to expand it further. Under what circumstances would the U.S. agree to an EU bubble that is or could be expanded?

EU Amendment to Convention

32. The EU has proposed an amendment to the Convention to provide for a vote to adopt all future protocols by three-fourths if all efforts at consensus are exhausted. The proposed amendment would appear to have a retroactive effect for Kyoto.

a) Under this proposal, is it possible that three-fourths of the FCCC Parties could vote to "adopt" any Protocol that imposed new obligations for Annex I and/or non-Annex I Parties and then decide not to deposit an instrument of ratification, etc.?

b) Does the U.S. support such an amendment to the Convention?

c) Has the U.S. position changed from its June 19, 1996 response to this Committee in regards to any of these matters? Would the Administration agree to a resolution of one of these matters, namely voting on a protocol, without a resolution of the financial and budget matters for both the Convention and all future protocols?

Emissions Trading

33. Does the Administration intend that any international emission trading program would apply in the same way and to the same extent to public and private entities internationally and in the U.S.? For example, would it apply to local governments and to defense or other agencies of each Party and to the emissions of such entities? What will be the impact on the U.S. Defense Department of an international, or, for the matter, a domestic, emissions trading program?

34. Greenhouse gases not covered by the Montreal Protocol are not pollutants within the meaning of the Clean Air Act and are not subject to the command and control provisions of the Act or other environmental laws. It is our understanding that although the U.S. has cited (in a September 9th reply to this Committee) authority to implement the Climate Change Action Plan with voluntary measures, the U.S. draft protocol, because it may call for mandatory measures, could not be given full effect in the U.S. without the enactment of new legislation by Congress. Do you share that understanding? Is the Administration considering a domestic emission trading legislative program patterned on the 1990 Clean Air Act?

General

35. I understand that the Administration has recently established the White House Climate Change Task Force, a Deputies Group and an Assistant Secretaries group. Please explain the role and purpose of each in regards to the development of the Administration's position and policies for the international negotiations for a protocol or another legal instrument in 1997 and for the development of implementing legislation in the U.S. Please identify the members of each group. Please provide any documents regarding the formation of these groups, their membership, mission, tasks, and/or assignments.

36. Please provide a table of all contracts, cooperative agreements, grants, and interagency agreements and any extensions thereof (hereinafter referred to as "agreements") entered into with any individual, agency, or public or private entity (foreign or domestic) by or through any federal Department or Agency, including the Departments of State, Commerce and Energy, and the Environmental Protection Agency, for the period beginning July 1, 1994 to the present that relates to, or includes, (directly or indirectly) climate change matters or issues of any kind. These should include matters relating to (a) domestic or international emission trading, including economic and other analysis of such trading, the administration and verification of such trading in the U.S. and elsewhere, (b) public outreach, general and specific public education, grass roots, community outreach, workshops, (c) transportation efficiency, alternative fuels, transportation generally, utilities, impact on pollutants like ozone and particulate matter, and (d) any legal analysis of these matters and of the Convention or of any statutes concerning climate change or trading. Each table should identify the date of the agreement, the agreement recipient, the amount of Federal funds, the term, including extensions, a brief description, the product and whether it is publicly available, and the status. Please include with each table the applicable "Statement of Work", including any revision thereof, for each such agreement.

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U.S. House of Representatives
Committee on Commerce
Room 2125, Rayburn House Office Building
Washington, DC 20515–6115

August 22, 1997

to M J
S H
Jae A

Todd Stern

The Honorable Janet Yellen
Chair
Council of Economic Advisors
Old Executive Office Building
Washington, D.C. 20502

Dear Ms. Yellen:

On July 15, 1997, you presented the Administration's views on the economic and environment impact of the proposed international global climate change agreement before the Energy and Power Subcommittee. On behalf and the members of the Subcommittee, I thank you for your informative testimony. The hearing was indeed enlightening.

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Thank you for your continued attention and assistance to the matter.

Sincerely,

Dan Schaefer
Chairman
Energy and Power Subcommittee

Attachment

cc: The Honorable Tom Bliley, Chairman
The Honorable John Dingell, Ranking Member
The Honorable Ralph Hall, Ranking Member
Subcommittee on Energy and Power

SUBCOMMITTEE ON ENERGY AND POWER
HEARING ON GLOBAL CLIMATE CHANGE
FOLLOW-UP QUESTIONS

Interagency Analytical Team Report

1. Please identify each member of the Interagency Analytical Team (IAT) from the date of its inception to the present time, any other participants inside or outside the Administration, and specify their responsibilities.

2. When was the IAT formed and what were the IAT's instructions? Please provide any documentation regarding the formation of the IAT and its mission, responsibilities, membership or assignments.

3. Please indicate the total costs of the IAT's efforts and the share paid annually by each Department or Agency that was involved and please identify the source of the funds within each Department or Agency.

4. Is the IAT still in existence? If so, what are its current responsibilities?

5. Please provide a copy of all drafts of the IAT report in addition to the May 16 and 30, 1997 drafts, both earlier and later.

6. Please explain how the peer reviewers were selected? What instructions were those peer reviewers given? Please provide copies of any correspondence or instructions that were sent to the peer reviewers.

7. If the IAT effort is in fact a "failed" project as indicated in Administration testimony at the Subcommittee hearing how will the Administration determine the appropriate level of future international climate change commitments for Kyoto and later?

8. As late as last May when Dr. Ehrlich and others in the Administration held briefings on the then draft analysis and assessment there was no hint that the Administration considered this effort a failure and the models to be unreliable. What occurred since May that caused the Administration to apparently reach a different conclusion from that of Dr. Ehrlich?

9. The IAT draft analysis referred to three scenarios which resulted in costs of future climate commitments of approximately $200, $100 or $50 per ton carbon tax equivalent. Has the Administration concluded that a $200 per ton carbon tax equivalent cost will not harm the U.S. economy, jobs, and global competitiveness? Has the Administration concluded that a $100 per ton carbon tax equivalent cost will not harm the U.S. economy, jobs, and global competitiveness? Has the Administration concluded that a $50 per ton carbon tax equivalent cost will not harm the U.S. economy, jobs, and global competitiveness. Please provide the basis for any of the above conclusions. If the Administration does not support any of the above costs, what analysis or other information does the Administration intend to rely on to support a different amount?

10. Is the paper prepared by the IAT both an analysis and assessment? How does it relate to the "analysis and assessment" referred to in Paragraph 4 of the Berlin Mandate? Has the Ad Hoc Group on the Berlin Mandate provided an analysis and assessment as required by the Berlin Mandate?

11. The IAT draft states that the central policy modeled for the analysis "is aimed at reducing carbon and other greenhouse gas emissions by stabilizing them at 1990 levels" and that policy would be "announced in 2000 and its restrictions are phased in over a ten year period, so that the policy would take full effect in 2010." Reports in the media after the Denver Summit that President Clinton attended also referenced this date of 2010. In light of EIA's projection of emissions 22% above 1990 levels by 2010, is the Administration considering a target and timetable that calls for stabilization at 1990 levels by 2010?

12. The Administration frequently cites the 2000 economists who say they support controlling greenhouse gases. Their statement supports as the mechanism either carbon taxes or emission permits. In the past, the Administration has said it opposes the use of taxes. Is that still the Administration's position?

13. The IAT draft explains that these emission reductions to achieve stabilization would be through "issuing tradable permits at the earliest point of energy production or when imported into the U.S." and that the permits "are initially auctioned in a way that is revenue neutral: i.e., all revenues generated would be recycled through the economy." Would these revenues be deposited in the treasury as miscellaneous receipts under the Economy Acts? Would they then have to be recycled through changes in the tax laws or by appropriation? How would they be recycled?

14. Does the Administration believe that permit auctions are the equivalent of a new tax? If not, please explain.

15. The IAT draft states that "among fuels, demand for coal bears the brunt of greenhouse gas stabilization." What is the impact on the U.S. economy as a whole and on the relevant coal regions of this policy towards coal? What will be the job impact? Is the Administration adopting an anti-coal policy? How is this policy consistent with President's Clinton 1995 reply to Mr. Dingell that the U.S. will not agree to any protocol that harms our economy and jobs or our competitiveness?

Kyoto Agreement

16. How long after December 1997 does the Administration think it will take to obtain Senate advice and consent of any Kyoto agreement, to ratify that agreement, and to enact implementing legislation?

17. Which Agency or Department would be responsible for implementing the provisions of any agreement reached in Kyoto, including provision relating to joint implementation, emissions trading, and advancing Article 4.1?

18. What consideration has been given or plans made regarding passage of legislation necessary to implement any agreement reached in Kyoto?

U.S. Draft Protocol

19. Article 17.4 of the Framework Convention on Climate Change (FCCC) specifies that only "Parties to the Convention may be Parties to a protocol." However, there is no assurance that all or even a majority of the 167 Parties to the FCCC will deposit instruments of ratification, acceptance, approval or accession to any protocol adopted by the Parties by consensus or otherwise in Kyoto. What assurances does the U.S. now have that most, if not all, developing country Parties to the FCCC will become Parties to a Kyoto protocol? Why is it in the U.S. interest to agree, without such assurances, to a protocol that proposes to set legally binding post-2000 targets and timetables for Annex I Parties only and also imposes on the U.S. new and legally binding commitments to advance implementation of Article 4.1. of the FCCC, such as those prescribed in paragraph 1, 2, 3, and 4 of Article 5 of the U.S. draft protocol?

20. In a July 18, 1994 letter to the then House Committee on Energy and Commerce, [the State Department] said:

> We agree that there are substantial commitments beyond 2000 for all parties to the Framework Convention under Article 4. Article 4.1 (applicable to both developed and developing countries) contains commitments that are not limited by any specific timetable.

a) Is there any evidence to date that the U.S. is not abiding by these Article 4.1 commitments? If there is none, why should the U.S. voluntarily agree to reaffirm, as required by Article 5.1 of the June draft, to what the U.S. already agreed to when it ratified the FCCC in 1992?

b) Is the U.S. asserting that other Annex I Parties are not abiding by such commitments? If so, please identify those Parties.

21. Paragraph 2 of Article 5 of the U.S. draft Protocol mandates each Party to "strengthen its legal and institutional framework to advance implementation" of Article 4.1 commitments. What "framework" does the Administration have in mind? Does this suggest a new Federal or international agency or program? Would this be done through new legislation? If not, how would it be achieved in the U.S.?

22. Article 5.3 requires that each Party take "measures to facilitate investment in climate-friendly technologies." What "measures" does the Administration contemplate? How would they be implemented in the U.S.? What are their regulatory and budgetary implementations?

23. Article 16 of the draft provides that the Parties "shall adopt, by [2005], binding provisions so that all Parties have quantitative greenhouse gas emissions obligations and so that there

is a mechanism for automatic application of progressive greenhouse gas emissions obligations to Parties, based upon agreed criteria."

a) Does this mean that there could be a second protocol or another legal instrument by [2005] which is only 7 years after the December meeting in Kyoto?

b) Do the words "all Parties" in this Article mean that only the "Parties" to the U.S. draft protocol would be required to "adopt" by 2005 such an instrument? Unless developing country Parties to the FCCC, such as China, India and Brazil, become Parties to the Kyoto instrument (as proposed by the U.S.) prior to [2005], how does this Article address the issue of greenhouse gas emission growth by all non-Annex I Parties?

c) Could such a new instrument adopted by [2005] impose new and additional obligations on the U.S. beyond those proposed to be adopted in Kyoto? Why is that possibility a good result for the U.S. economy, trade, and competitiveness?

d) What "mechanism for automatic application of progressive greenhouse gas emissions obligations" does the Administration contemplate by this proposal? What are its implications for the U.S., including its sovereignty?

24. Article 16.1 of the Convention provides that "annexes shall be restricted to lists, forms, and any other material of a descriptive nature that is of a scientific, technical, procedural or administrative character." The U.S. draft protocol states, that it may not be "appropriate" to adopt the Article 16.1 Convention example. Please explain why. Does the U.S. support annexes that would be substantive and mandatory?

25. Article 9 of the U.S. draft provides that Parties "shall cooperate" in establishing a "long-term goal" regarding concentrations of gases. Article 10 calls for meetings at "regular intervals" to, among other things, "periodically review the adequacy" of the Protocol and Article 8 calls for periodic review of the Protocol and guidelines "in light of evolving scientific knowledge related to climate change." Article 2 already suggests a minimum of two budget periods. Article 16 tells the Parties to adopt "binding provisions" by [2005] for progressive "obligations." Does the State Department contemplate over the next several decades a continuing process of meetings of both the Protocol and Convention Parties annually and a series of IPCC assessments, special reports, and technical papers, leading to a series of protocols or other legal instruments that are likely to have significant economic impacts on the Parties and their people? Why is there a need for such frequent meetings and reviews?

26. The Global Climate Coalition sent a letter to the Department of State on February 14, 1997 raising a number of questions about the January 17, 1997 version of the U.S. draft protocol, particularly in regards to trading. The Administration has not yet responded to those questions. Please respond to them as part of your reply to this inquiry.

EU Bubble

27. The EU proposal made recently in Denver was developed last March as an EU "negotiating position for the ongoing negotiations on the Berlin Mandate" and it includes burden-sharing of a 10% reduction among EU members of the "overall emission reduction objective by the Community as a whole". This appears to be a form of differentiation, a concept the U.S. is not supporting. The existing FCCC bubble applicable to the EU presumably only covers policies and measures and, when adopted, it only covered the 12 Parties that were members of the EU in 1992. Does the U.S. understand that the EU is seeking, by its submissions and discussion with the U.S. delegation, to extend a form of the FCCC bubble to a protocol and another legal instrument that may be adopted in Kyoto, to expand the bubble to cover any target and timetable or financial obligations and not just policies and measures, and to expand the bubble to include all present and future members of the EU, such as countries from Central and Eastern Europe? Why is such an expanded bubble in the economic and competitive interests of the U.S.?

28. What is the potential impact of such an expanded EU bubble on the U.S. proposal for international emissions trading? Would it ensure that the EU would get the benefit of any emissions deficit derived from such Central and Eastern European Members and deprive the U.S., Japan, Australia and Canada of that deficit? Would the U.S. then have to rely primarily on Russia's emissions deficit in order to derive any of the benefits of trading?

29. Article 22.3 of the FCCC requires that regional economic integration organizations must declare the "extent of their competence" with regard to obligations under the FCCC. Does the U.S. believe that the EU has the competence to carry out legally binding targets and timetables and to enforce any differentiated targets for its members if they fail to achieve them?

30. The State Department's September 9, 1996 reply to the Committee stated that the U.S. did not agree to an "EU Bubble in Berlin" and that the U.S. delegation "successfully opposed including language in the Berlin Mandate which might have suggested that any country or group of countries could "bubble" in the post-2000 period." The reply then said:

> Clearly, the question of "bubbling" with respect to post-2000 commitments is complex, and one that will be closely scrutinized and carefully considered as negotiations progress. The Administration has consistently and continuously consulted with Congress, as well as with U.S. industry and U.S. NGOs, on all aspects of the negotiations concerning post-2000 commitments and will continue to do so.

The Administration has not yet held meaningful discussions with this Committee on the issue of the EU bubbling to "meet and target and timetables," its implications for the U.S., its merits, or its complexities. Given the fact that negotiations are just approaching a conclusion in Bonn and Kyoto, when do you plan to consult us on this aspect of the negotiations?

31. Since 1992, the composition of the only "regional economic integration organization," namely the EU, has grown from 12 to 15 members and several other countries want to expand it further. Under what circumstances would the U.S. agree to an EU bubble that is or could be expanded?

EU Amendment to Convention

32. The EU has proposed an amendment to the Convention to provide for a vote to adopt all future protocols by three-fourths if all efforts at consensus are exhausted. The proposed amendment would appear to have a retroactive effect for Kyoto.

a) Under this proposal, is it possible that three-fourths of the FCCC Parties could vote to "adopt" any Protocol that imposed new obligations for Annex I and/or non-Annex I Parties and then decide not to deposit an instrument of ratification, etc.?

b) Does the U.S. support such an amendment to the Convention?

c) Has the U.S. position changed from its June 19, 1996 response to this Committee in regards to any of these matters? Would the Administration agree to a resolution of one of these matters, namely voting on a protocol, without a resolution of the financial and budget matters for both the Convention and all future protocols?

Emissions Trading

33. Does the Administration intend that any international emission trading program would apply in the same way and to the same extent to public and private entities internationally and in the U.S.? For example, would it apply to local governments and to defense or other agencies of each Party and to the emissions of such entities? What will be the impact on the U.S. Defense Department of an international, or, for the matter, a domestic, emissions trading program?

34. Greenhouse gases not covered by the Montreal Protocol are not pollutants within the meaning of the Clean Air Act and are not subject to the command and control provisions of the Act or other environmental laws. It is our understanding that although the U.S. has cited (in a September 9th reply to this Committee) authority to implement the Climate Change Action Plan with voluntary measures, the U.S. draft protocol, because it may call for mandatory measures, could not be given full effect in the U.S. without the enactment of new legislation by Congress. Do you share that understanding? Is the Administration considering a domestic emission trading legislative program patterned on the 1990 Clean Air Act?

General

35. I understand that the Administration has recently established the White House Climate Change Task Force, a Deputies Group and an Assistant Secretaries group. Please explain the role and purpose of each in regards to the development of the Administration's position and policies for the international negotiations for a protocol or another legal instrument in 1997 and for the development of implementing legislation in the U.S. Please identify the members of each group. Please provide any documents regarding the formation of these groups, their membership, mission, tasks, and/or assignments.

36. Please provide a table of all contracts, cooperative agreements, grants, and interagency agreements and any extensions thereof (hereinafter referred to as "agreements") entered into with any individual, agency, or public or private entity (foreign or domestic) by or through any federal Department or Agency, including the Departments of State, Commerce and Energy, and the Environmental Protection Agency, for the period beginning July 1, 1994 to the present that relates to, or includes, (directly or indirectly) climate change matters or issues of any kind. These should include matters relating to (a) domestic or international emission trading, including economic and other analysis of such trading, the administration and verification of such trading in the U.S. and elsewhere, (b) public outreach, general and specific public education, grass roots, community outreach, workshops, (c) transportation efficiency, alternative fuels, transportation generally, utilities, impact on pollutants like ozone and particulate matter, and (d) any legal analysis of these matters and of the Convention or of any statutes concerning climate change or trading. Each table should identify the date of the agreement, the agreement recipient, the amount of Federal funds, the term, including extensions, a brief description, the product and whether it is publicly available, and the status. Please include with each table the applicable "Statement of Work", including any revision thereof, for each such agreement.

Congressional Testimony

Note to: Dan Tate
Katie McGinty
Todd Stern

From: Dirk Forrister

Here are our notes from the hearing yesterday. Would you suggest further distribution?

Climate Change Hearing
House Commerce Committee
Subcommittee on Energy and Power
July 15, 1997

Members attending:

Dan Schaefer, Subcommittee Chair (R-CO)
Tom Bliley, Full Committee Chair (R-VA)
Michael Crapo (R-ID)
Rick White (R-WA)
James Rogan (R-CA)
Edward Whitfield (R-KY)
John Shimkus (R-IL)
Ralph Hall, Ranking subcommittee member (D-TX)
Ed Markey (D-MA)
Tom Sawyer (D-OH) [not on subcommitte; just sitting in]
Karen McCarthy (D-MO)

Witnesses:

Tim Wirth, Undersecretary for Global Affairs, U.S. Dept. of State
Janet Yellen, Chair, President's Council of Economic Advisors

In general, the Republican members were astonished that the Administration is backing away from the long-promised analysis and assessment. They were particularly surprised by Dr. Yellen's characterization of the IAT effort as a "failed project" and a "futile exercise." Toward the end, they were almost pleading to be consulted prior to the Kyoto meeting.

Mr. Schaefer began by saying that this is the first hearing of the 105th Congress. He was pleased to finally get some real information in the form of the draft economic analysis and assessment and the peer review comments and he looked forward to hearing what the Administration thinks of the numbers. He wants to know what is Administration policy and what is not, and at least narrow the range of the options on the table. He agrees with the Administration that any actions must be reasonable and achieveable and that flexibility is key. He is looking for assurances that the Administration will not rush to judgement in December 1997, and will not sign an agreement that results in tranferring emissions and jobs overseas.

Markey said nice things about Wirth. He then said that he thought today was an appropriate day to have this hearing--with temperatures expected to top 102 degrees and ozone expected to hit dangerous levels. He quoted Mark Twain's comment that everybody talks about the weather but nobody ever does anything about it, but that he hopes there will be real action in Kyoto. He applauded the Clinton Administration for their leadership, and expressed his confidence that the Administration is basing its policy on the best scientific information and a clear understanding of the economic implications. He said he is particularly interested in energy conservation and

renewables, and in the role of India and China.

Bliley said that in 2 weeks the Administration will be negotiating in Bonn, and in less than 6 months, if things go as planned, we'll have an agreement, and yet when he looks at the Administration's proposal he sees a piece of paper with the most critical elements blank. He's glad to see a draft of the long promised analysis, but concerned that stabilization at 1990 levels by 2010 will require the "equivalent of a tax" of 26 cents/gallon of gasoline, 2 cents /kwh, $52.50/ton of coal; $1.49/MCF natural gas. (Several members used the phrase "the equivalent of a tax") Going 10% below doubles the cost; 10% above cuts the cost in half. The analysis raises more questions than it answers. How do our costs compare to Europe's? Will Europe get an economic advantage from this treaty? How do we know we're not just moving emissions and jobs overseas? He said that because he has questions does not mean that he isn't concerned about the environment.

Dingell expressed concern about the ambitious negotiating schedule. Kyoto is less than 5 months away. He applauds the Administration for providing some of the information the Committee had requested. He wants to know what impact the information will have on the negotiations. He quoted a letter he received from President Clinton in 1995 which said (a) that this process must reflect thoughtful analysis and (b) that he won't agree to anything that will adversely affect U.S. competitiveness. Dingell said that the negotiating parameters of the Berlin mandate, which rule out developing coutnry commitments, rule out protecting American competitiveness. The Administration agreed in Berlin last year to develop, at early stages, an analysis and assessment of possible policies for Annex I countries to adopt. [There seemed to be some confusion about this international analysis and assessment which the IPCC completed last year, which is different from the analysis and assessment which the Administration promised. Wirth cleared this up later.] We have already provided our negotiating text; the public has little opportunity to comment on the analysis..."I wonder how anybody can be comfortable with theis process...How has the Administration been able to progress so far so fast without this information?"

Whitfield said that he has met with labor business and environmental interests and that they all agree that the climate change issue has greater impact on the U.S. than any other environmental issue we've considered recently. He has been concerned that that Adminstration has been reluctant to say where it's headed, and there's been a lack of information and candor. He is worried about the equivalent of a $95 or $100 per ton carbon tax. He is is worried that Wirth told the Senate a couple of weeks ago that the reason we have to go from voluntary to involuntary targets is that the U.S. economy is doing too well.

Shimkus said it's warm in southern Illinois so he doesn't mind the heat. He's worried about closing factories, closing coal mines. He knows there's angst about discussing jobs and the environment, but he's not sure the science is there yet on this issue.

White said he has no preconceived notions on this issue. The central issue for him is how to figure out how to spend our scarce resources when we don't have all the information we need. We need to protect our environment, but we need to do in the most cost-effective way. We really don't know what greenhouse gas emissions are doing to the climate, but some want to err on the

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difference is between legally binding and binding because the Vienna Convention on the Law of Treaties says that every treaty is binding. Wirth said he would consult with lawyers at State and get back to him. Whitfield asked about the U.S. position on developing countries and Wirth explained it. Whitfield asked if the Administration is moving toward an anti-coal policy. Wirth said no, the U.S. policy is to reduce greenhouse gases while maintaining a strong U.S. economy.

McCarthy asked about the economists' letter and the WRI study. Yellen talked about the importance of technology and investment and market signals. She said the economics literature provides useful guidelines but that ultimately one needs to make a judgement. Wirth mentioned the Los Alamos study (I think he meant the 5 labs study which isn't out yet.) Yellen said there are better and worse ways to do this. Flexibility in time and place is key. The tradeable permit program for acid rain is a good model. Revenue recycling would provide opportunities to reduce other taxes. If we do this sensibly, we can end up with a win for the economy. We're at the end of the road on the IAT exercise

Schaefer asked how developing countries have responded to JI and trading. Wirth said not as well as we would like. Schaefer said he likes trading.

Yellen said we should not place reliance on any particular model or range of models or expect to find precision. It's a futile exercise. We are not going to continue in any search for perfection. There is no model that accounts for everything. Economic analyses do offer us a range of insights. Models give a roughhand look at how much difference different approaches could make.

Shimkus tried to ask a question about the satellite data, but he flubbed the question when Wirth asked him to clarify. He thinks the science isn't clear. Wirth offered to set up a science briefing for him. Shimkus asked where should we spend our money--reducing emissions in the U.S. at high cost or in developing countries at low cost. Yellen said that there are high and low cost opportunities in both places. The virtue of a market system is that it creates incentives to find the cheapest reductions anywhere. Shimkus said he is interested in JI and international trading. He also said he wants to give good guys credit for early reductions. Yellen said that the Administration has no policy as to how we would achieve reductions (she said "we have no policy" a few times during the hearing), the price of fossil fuels should be higher to take into account environmental damage. Wirth said we don't have a package of proposals, but you would want to give credit to ones who have done well. Shimkus said it is important that this committee and this body make the decisions and that the Administration not do it by rules.

Correct Yellen on this

Markey pointed out that this committee would be the one to make these decisions. He said that he is worried about sea level rise, although he is intrigued by the possibility of his hometown becoming beachfront property. He asked, "What are the benefits of dealing with climate change?" Yellen said that if we fail to take steps now, new plants will be built without taking into account climate change. Then when we finally decide we need to do something later, it might be unduly expensive. Wirth told a story about how people in Florida east of I-95 are losing their insurance because of all the storms. Markey also asked about the renewables standard in electricity restructuring debate. Wirth pointed out that the treatment of stranded costs for nuclear power

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side of caution.

McCarthy talked about her experience on a Missouri state commission looking at climate change issues. She said we need to make sure developing countries join in this process. We also need to educate the public at home. She sees climate change as a national security issue. If implemented right, it can be clearly positive for the U.S. (e.g., in Missouri they found that alternative fuels are an economic winner.)

Dr. Yellen said that the costs depend on a number of critical assumptions. If we do it dumb, it's expensive. If we do it smart, it's not so bad. Developing countries must be part of the process.

Undersecretary Wirth said the science is clear and compelling. We agree that the developing countries must take on commitments. The issue is when. The developed and developing countries have common but differentiated responsibilities. It is neither realistic nor consistent with the Climate Convention approved by the Senate to require developing countries to be on the same schedule as the developed countries. The Administration welcomes your ideas and support.

Schaefer's first question was on the Argonne report. Yellen's response wasn't quite right. She said that the Argonne scenarios came from the base case in the IAT report, which assumed no flexibility in implementation. He asked her what the scenarios were and she said she would provide that for the record. Regarding the IAT report, Yellen said the staff focused on a scenario that was not Administration policy. She said the analysis is concluding because it's futile. Schaefer said that he is surprised that we still don't have the analysis that was promised in the last Congress.

Dingell gave Wirth andYellen a hard time. He tried to get them to say that all of the important decisions (e.g., leaving out developing countries) were made without doing any analysis, but Yellen pointed out that the targets and timetables haven't been decided yet. The U.S. position on flexibility and developing countries is settled, she said. Dingell said the analysis is too little too late. Dingell asked Yellen whether developing countries get a huge advantage by not having requirements, and she said that it depends how it is implemented. Wirth said that the U.S. position is that developing countries will have to do some things. Dingell said "but there are no enforcement mechanisms," and Wirth said that there are no enforcement mechanisms for our commitments either. Dingell said he is worried that the Administration will just do this by regulation, like they did with PM and ozone, and not bother with implementing legislation. Schaefer chimed in and quoted from an EPA analysis that said that EPA could impose a 50 cents/gal gasoline fee without new legislation. Dingell tried to get Wirth to promise that the Administration wouldn't use its regulatory authorities, but Wirth demurred.

Wirth said that there are discussions going on between the Administration and the House leadership on setting up a Congressional observer group for the negotiations. He suggested that interested members should join.

Whitfield asked what the significance of legally binding targets are if there is no enforcement mechanism. Wirth said that nations just generally comply. Whitfield also asked what the

plants is the restructuring debate is also relevant for climate change. Markey said he thinks the treatment of stranded costs should be a state decision, but a national renewables standard is a good idea.

Rogan asked about the timing of the analysis. Wirth explained that we had hoped to have it by the first of this year. The modeling was harder than we thought it would be. The predictive power is less than we had hoped. We're not going to go any furthre with this exercise.

Crapo said "You're not going to continue with economic analysis?" Yellen said we are still going to do analysis, but we will not rely on a asingle model or small group of models. The tool kit has nt worked. For any policy we propose, we will testify on its economic impact. We will share all kinds of analyses of particular issues. There is no expectation that there will be a final draft.

Rogan asked, "If we ask how will this impact the iron and steel industries, will you be able to answer?" Yellen said no. "Are we going to be able to hear before December on a solid economic analysis of particular industries?" Yellen said if you're expecting forecasts of jobs in the steel industry by 2020, the answer is no. Rogan said that Argonne National Lab wasn't reluctant to do this type of analysis, and they said this treaty will devastate the steel industry. Yellen said the Argonne report didn't assume flexibility. The price scenarios were based on relatively stringent and rigid policies. President Clinton's #1 priority has been jobs and the economy; he would not support bad policies.

Hall said nice things about Wirth. Hall asked whether the current draft is the last draft. Yellen said it is in many ways a failed project. Hall was concerned that the President said the new air quality standards are a positive first step but more to follow. Wirth explained that there were three models--a DOE model, and EPA model, and the DRI model. (This isn't quite right.) Hall asked if we have time to do the necessary work by December. Wirth said that it's like an election, you do whatever you can by election day. Hall said it looked like if the work isn't done, we'll get an agreement anyway.

Crapo said that for 2 years we have expected an economic analysis and policy to be based on that analysis--and now we find out it is a failed project. Wirth described the effort as trying to build a composite model of three models, and we failed. (That isn't what we were doing at all.) Crapo said Congress is supposed to have a role in this. Is there going to be some time when the Administration tells us what their economic analysis is so that we can participate? The President is going to ask us and the rest of America what he should do. This is going to be dropped in our lap. Is there some time that the President will tell this Committee anything?

Wirth said that we will come to a conclusion on targets and timetables at the end of October. This will be presented to Congress prior to October. (Is this true?) Wirth suggested that members work with us through the observer group. Crapo said he is still at a loss as to when Congress will get the information on which to base policy. "We want to engage with you."

Crapo asked if Wirth acknowledges that what he does will be subject to a vote in the Senate. Wirth said yes, and it will require enabling legislation.

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Hall said we'd like to have some input "before the fact, rather than you bringing something back that I in the oil patch and Dingell in Michigan can't live with."

Pallone was friendly. He said he liked the Presidnet's speech. He's interested in the renewable energy industry and in joint implementation. Yellen said we want to see credits for joint implementation.

Schaefer concluded that all we're asking is that before you act, you tell us the options and the economic implications. People are starting to ask us about this.

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THE ECONOMICS OF CLIMATE CHANGE

Testimony to the Committee on Environment
and Public Works, U.S. Senate
by
Dale W. Jorgenson
Professor of Economics, Harvard University

Mr. Chairman, distinguished members of the Committee on Environment and Public Works: I am very grateful for the opportunity to participate in these Hearings on the scientific understanding of global climate change. My testimony will focus on the economics of climate change. As a point of departure I will use the "Economists' Statement on Climate Change" included in my written testimony. I was one of five co-authors of this statement, which was circulated in January of this year and has now been endorsed by 2600 economists, including eight Nobel prize winners.

The first paragraph concludes that global change involves significant environmental risks and preventive steps are justified. The second paragraph summarizes economic studies showing that there are policies for reducing greenhouse gas emissions with benefits that outweigh the costs. The third paragraph describes these policies in more detail and emphasizes the importance of relying on market-based mechanisms.

The economics of climate change can usefully be divided into three parts. The first is determination of the overall objective of climate policy. The economists' approach to this problem is to choose a policy that produces the greatest margin of benefits over costs. Using economic jargon, I will refer to this as the "optimal" policy. Such a policy would stipulate a time path for future emissions of greenhouse gases that could be embodied in an international agreement.

After an overall objective is chosen, the second step is to devise a means of implementing this goal. Emissions of greenhouse gases would have to be allocated among the signatories of an agreement. In addition, emissions by countries that are not signatories would have to be taken into

Mr KL

account, since the global climate is affected by total emissions. Third, given an allocation of greenhouse gas emissions among countries, each country would have to implement its emissions goal by devising policies that would hold emissions within the prescribed quota. Furthermore, the international community would have to monitor emissions for all countries.

Let me begin with an evaluation of our existing climate policy, the Climate Change Action Plan (CCAP) of 1993. This Plan consisted of voluntary actions projected to reduce emissions to 1990 levels by the year 2000. The goal was stipulated in the United Nations Framework Convention on Climate Change ratified by the United States in October 1993.

The impact of CCAP is summarized in the final chart, which compares a projection of U.S. emissions of greenhouse gases under the original CCAP "baseline," projecting emissions without the Plan. The CCAP actions were projected to reduce emissions to 1990 levels by the year 2000. The third line on the chart gives actual U.S. emissions through 1996. These are above the CCAP baseline and far above emissions levels required for stabilization. Clearly, we need to consider alternatives to our existing climate policy.

The starting point for a discussion of climate policy is the damages associated with a change in the climate. This is based on combining a physical description of the climate with an economic description of the world economy. This type of analysis is called "integrated assessment" and an assessment of this type has been carried out by William Nordhaus of Yale University in his 1994 book. The loss associated with climate change is 1.34 percent of world product in 2050.

How large are the damages associated with climate change? They are equivalent to the loss of about one year of world economic growth. Obviously, this is sizable, but not overwhelming. In the view of the signatories of the Economists' Statement on Climate change, this is sufficient to justify preventive steps to reduce greenhouse gas emissions.

Next, suppose we choose reductions in emissions that will produce the maximum difference between costs and benefits. How large are the benefits of this policy? Nordhaus has calculated the benefits for the world as a whole to be equivalent to $271 billion dollars. This is only 0.04 percent of future consumption! While damages associated with climate change are substantial, steps to mitigate these damages will produce only very modest effects.

Let me emphasize at this point that the policy I have described conforms to the Economists' Statement on Climate Change. Preventive steps are justified. Policies like the one I have described would reduce greenhouse gas emissions and could employ market-based mechanisms to do so. A policy appropriate for international implementation would be the system of internationally tradeable permits described in the U.S. Climate Change Proposal of January 17.

For domestic implementation of the optimal climate change policy an appropriate market mechanism would be to impose taxes on greenhouse gas emissions. These taxes would be relatively modest, amounting to an initial tax of $5.29 per ton of carbon and rising to $10.03 per ton by the year 2025. My paper with Peter Wilcoxen, "The Economic Effects of a Carbon Tax," analyzes the effects of a tax on emissions of carbon dioxide, the most important greenhouse gas, in greater detail.

Wilcoxen and I calculate the cost of achieving various goals, including the stabilization goal of the United Nations Convention. We also consider different methods for "recycling" the revenues from a carbon tax and find that the economic cost is highly dependent on the use of the revenue. Finally, we consider the use of alternative tax instruments, such as a "Btu" tax on energy and an *ad valorem* tax on energy.

Our overall conclusions are, first, that a carbon tax is superior to other tax instruments. Second, by using the revenues to reduce the most burdensome taxes, namely taxes on income from capital, economic growth can be stimulated rather than retarded. Of course, reducing the tax burden on capital by substituting other forms of taxation would produce similar effects with no effect on emissions of greenhouse gases.

To sum up: The economics of climate change is well understood. The optimal policy, described in more detail in my written testimony, involves a modest reduction in the growth of greenhouse gas emissions. This should provide the basis for any international agreement that would supersede the United Nations Framework Convention of 1994. However, this involves smaller reductions than our existing climate policy, the U.S. Climate Change Action Plan.

The U.S. Climate Change Proposal from last January contains a useful contribution to international implementation by proposing a system of internationally tradeable permits for emissions. Domestic implementation requires a process for setting country-specific quotas for emissions. This might impose lower or higher reductions in emissions for the U.S., relative to other countries. After the U.S. quota has been determined, the final step would be to impose a tax on emissions like the carbon tax discussed in my paper with Wilcoxen.

TESTIMONY TO THE
U.S. SENATE COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS

THE ECONOMICS OF
CLIMATE CHANGE

by

Dale W. Jorgenson

Professor of Economics

Harvard University

Thursday, July 10, 9:30 a.m.

Room 406

Dirksen Senate Office Building

Washington, D.C.

SHORT READING LIST

William J. Clinton and Albert Gore, Jr., THE CLIMATE CHANGE ACTION PLAN, Washington, Executive Office of the President, October 1993.

Dale W. Jorgenson and Peter J. Wilcoxen, "The Economic Effects of a Carbon Tax," in Henry Lee (ed.), SHAPING NATIONAL RESPONSES TO CLIMATE CHANGE, Washington, The Island Press, 1995, pp. 237-260.

William D. Nordhaus, "Analysis of Policies to Slow Global Warming," Chapter 5 in MANAGING THE GLOBAL COMMONS, Cambridge, The MIT Press, 1994, pp. 77-100.

The World Bank, "International Environmental Concerns," Chapter 8 in DEVELOPMENT AND THE ENVIRONMENT, New York, Oxford University Press, 1992, pp. 153-169.

WHAT IS THE PROBLEM?

GLOBAL CLIMATE AS A
COMMON PROPERTY RESOURCE

GLOBAL ECONOMIC DAMAGE:
1.34 PERCENT OF WORLD PRODUCT
IN THE YEAR 2050

THIS IS EQUIVALENT TO ONE
YEAR'S ECONOMIC GROWTH!

THE ECONOMIST'S POLICY RESPONSE

POLICY INSTRUMENT:

A WORLD CARBON TAX

AN OPTIMAL TRANSITION PATH

FOR SLOWING CLIMATE CHANGE

PRODUCES A BENEFIT OF

$271 BILLION
U.S. DOLLARS OF 1989

PRACTICAL IMPLEMENTATION

INTERNATIONAL COORDINATION:

A POSSIBLE FRAMEWORK AGREEMENT

POLICY INSTRUMENT:

INTERNATIONALLY TRADEABLE PERMITS

DOMESTIC POLICIES:

NATIONAL CARBON TAXES

TWO ALTERNATIVE POLICIES

THE RIO EARTH SUMMIT:

STABILIZE THE CLIMATE

CLINTON-GORE ACTION PLAN:

STABILIZE EMISSIONS

A MORE LIMITED ECONOMIST'S ROLE:

MINIMIZING THE COST OF

ACHIEVING THESE OBJECTIVES

EVALUATING THE ALTERNATIVES

STABILIZING EMISSIONS

RESULTS IN AN ADDITIONAL COST OF

$7.069 TRILLION
U.S. DOLLARS OF 1989

STABILIZING THE CLIMATE

ADDS A FURTHER COST OF

$12.521 TRILLION
U.S. DOLLARS OF 1989

DOING NOTHING IS SUPERIOR TO

EITHER OF THESE ALTERNATIVES!

THE CLIMATE CHANGE ACTION PLAN

STABILIZING EMISSIONS AT 1990 LEVELS BY THE YEAR 2000

FIFTY ACTIONS INVOLVING ALL SECTORS OF THE ECONOMY

NO TRADEABLE PERMITS; NO ENERGY TAXES

A PRACTICAL BEGINNING

1. ELIMINATE SUBSIDIES TO ENERGY CONSUMPTION

2. SUBSTITUTE ENERGY TAXES FOR INCOME TAXES

ECONOMISTS' STATEMENT ON CLIMATE CHANGE

Endorsed by Over 2000 Economists
including six Nobel Laureates

I. The review conducted by a distinguished international panel of scientists under the auspices of the Intergovernmental Panel on Climate Change has determined that "the balance of evidence suggests a discernible human influence on global climate." As economists, we believe that global climate change carries with it significant environmental, economic, social, and geopolitical risks, and that preventive steps are justified.

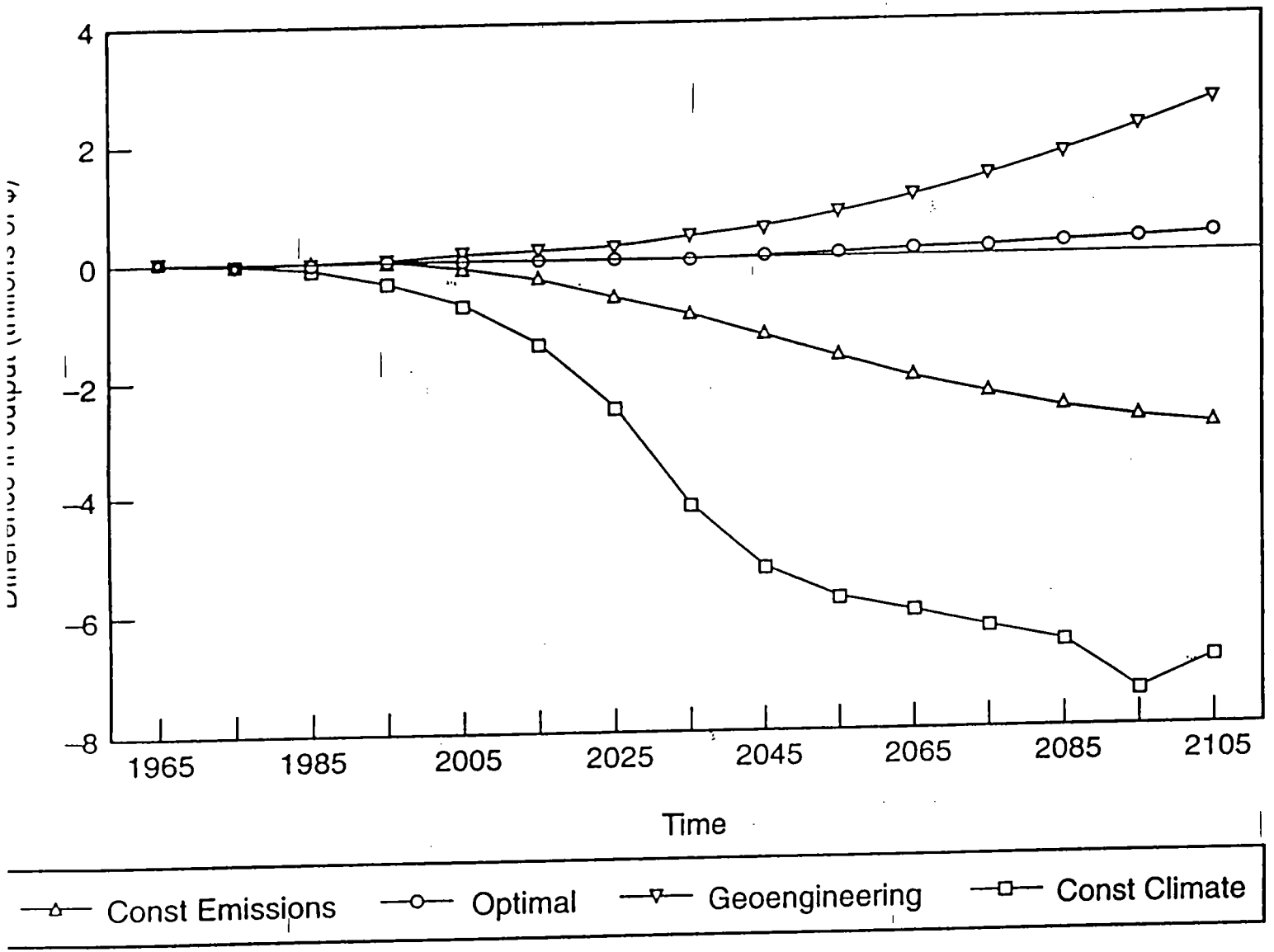
II. Economic studies have found that there are many potential policies to reduce greenhouse-gas emissions for which the total benefits outweigh the total costs. For the United States in particular, sound economic analysis shows that there are policy options that would slow climate change without harming American living standards, and these measures may in fact improve U.S. productivity in the longer run.

III. The most efficient approach to slowing climate change is through market-based policies. In order for the world to achieve its climatic objectives at minimum cost, a cooperative approach among nations is required—such as an international emissions trading agreement. The United States and other nations can most efficiently implement their climate policies through market mechanisms, such as carbon taxes or the auction of emissions permits. The revenues generated from such policies can effectively be used to reduce the deficit or to lower existing taxes.

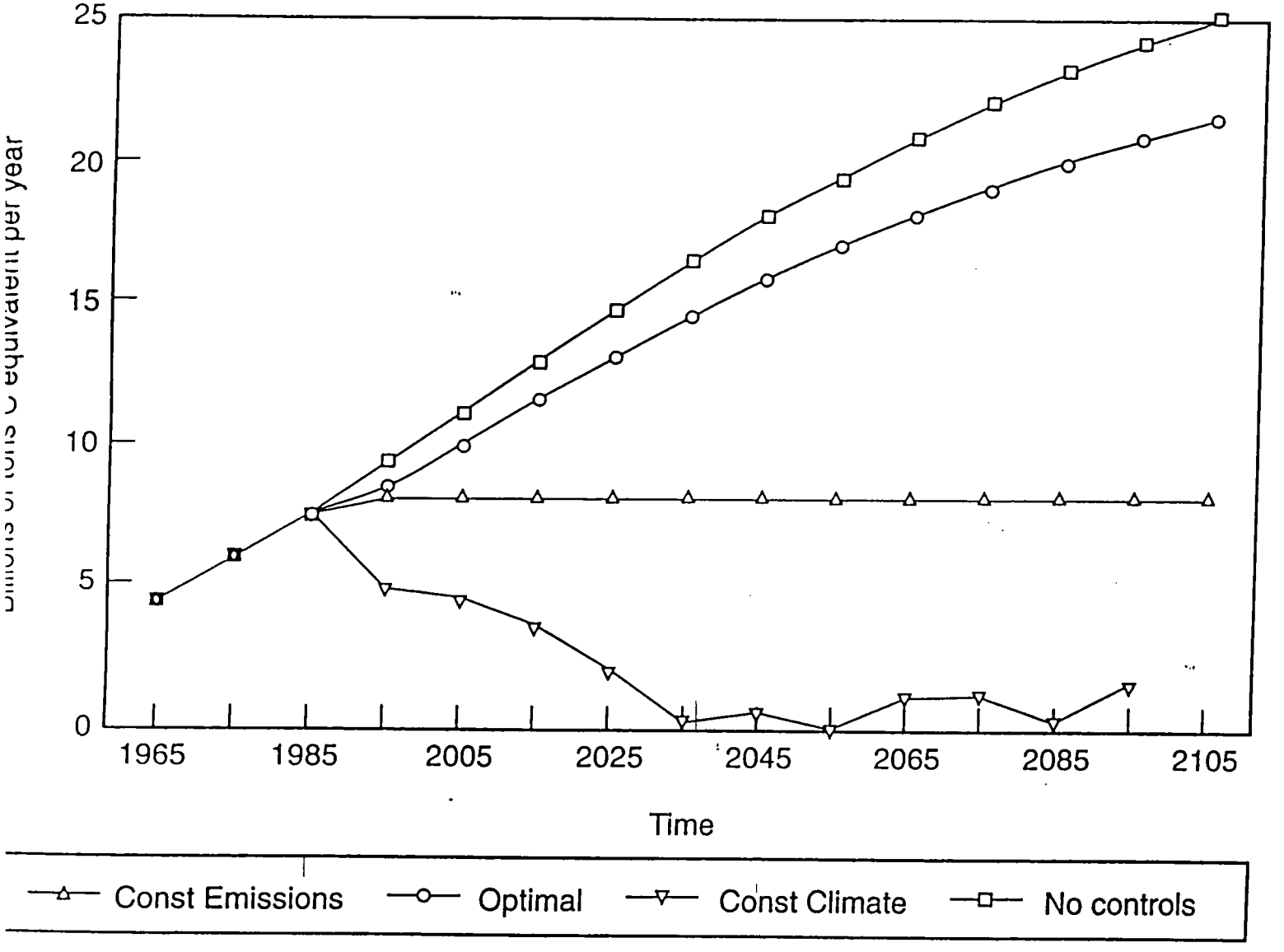
Table 5.1
Net benefit of alternative policies on discounted consumption

Case	Policy	Discounted Value of Consumption			Impact on Annualized Value of Consumption (billions of $/yr.)
		Base Value (trillions of 1989 U.S.$)	Impact of Program: Difference (billions of $)	Percent Difference	
1	No mitigation	730.90	0	0.00	0
2	Optimum	731.17	271	0.04	11
3	10-year delay	731.14	243	0.03	10
4	Stabilize emissions at 1990 level	723.83	(7,069)	(0.98)	(283)
5	Stabilize emissions at 80 percent of 1990 level	718.38	(12,521)	(1.74)	(501)
6	Geoengineering	736.50	5,601	0.76	224
7	Stabilize climate at maximum of 1.5 degrees C increase	689.92	(40,980)	(5.94)	(1,639)

Notes: The present value of consumption is calculated as the consumption stream from 1990 on discounted to 1990 at the rate of interest on goods and services calculated in the optimal program. Values in parentheses indicate negative values. All values are in 1989 U.S. dollars. Annualized consumption is calculated at rate of interest less rate of growth (equal to .04) times discounted value of consumption.



igure 5.1
)ifferences in global output
)ifference from no-controls baseline, trillions 1989 U.S. dollars)



gure 5.2
eenhouse-gas emissions
O_2 and CFCs only)

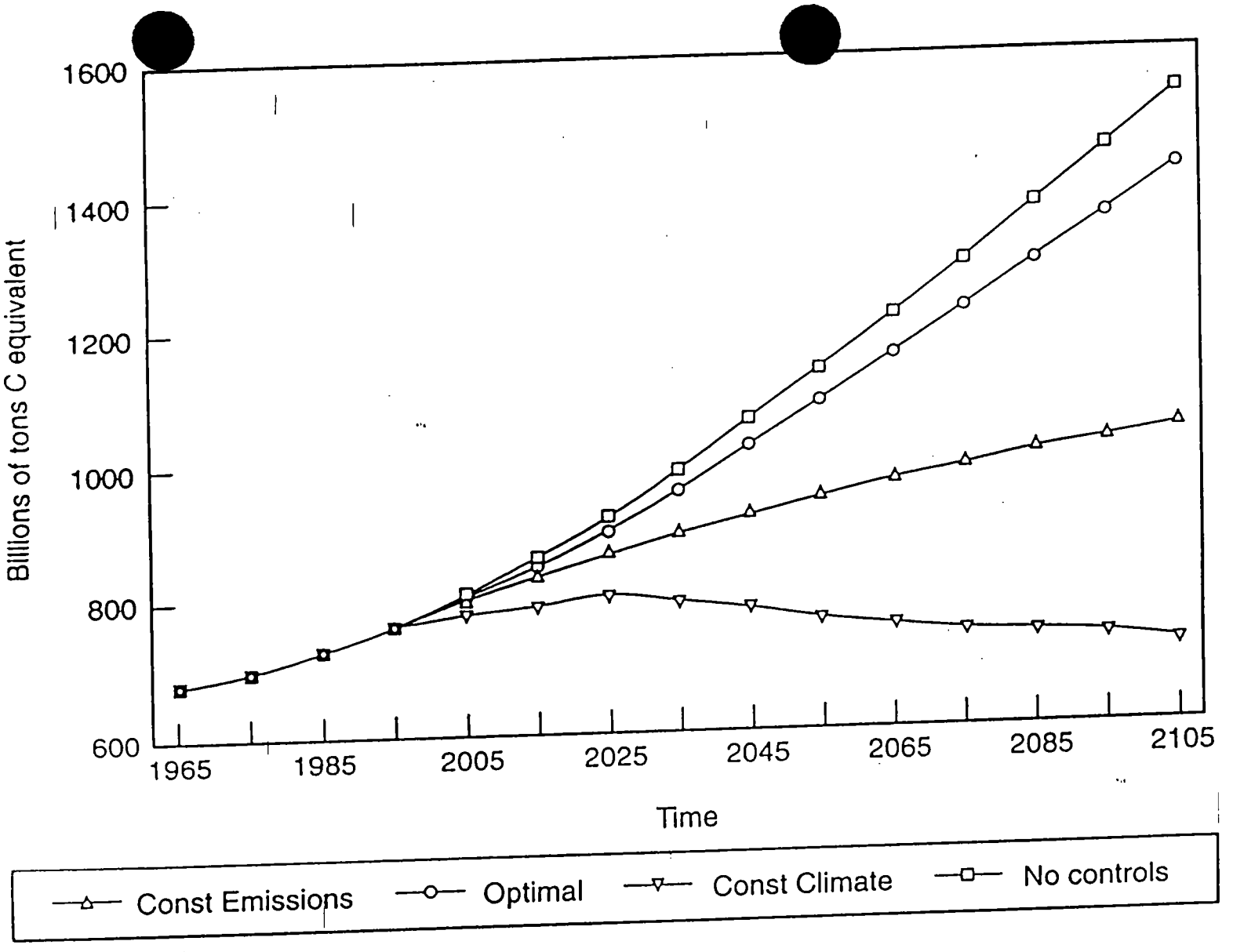


Figure 5.3
Atmospheric GHG concentrations
(CO_2 and CFCs only)

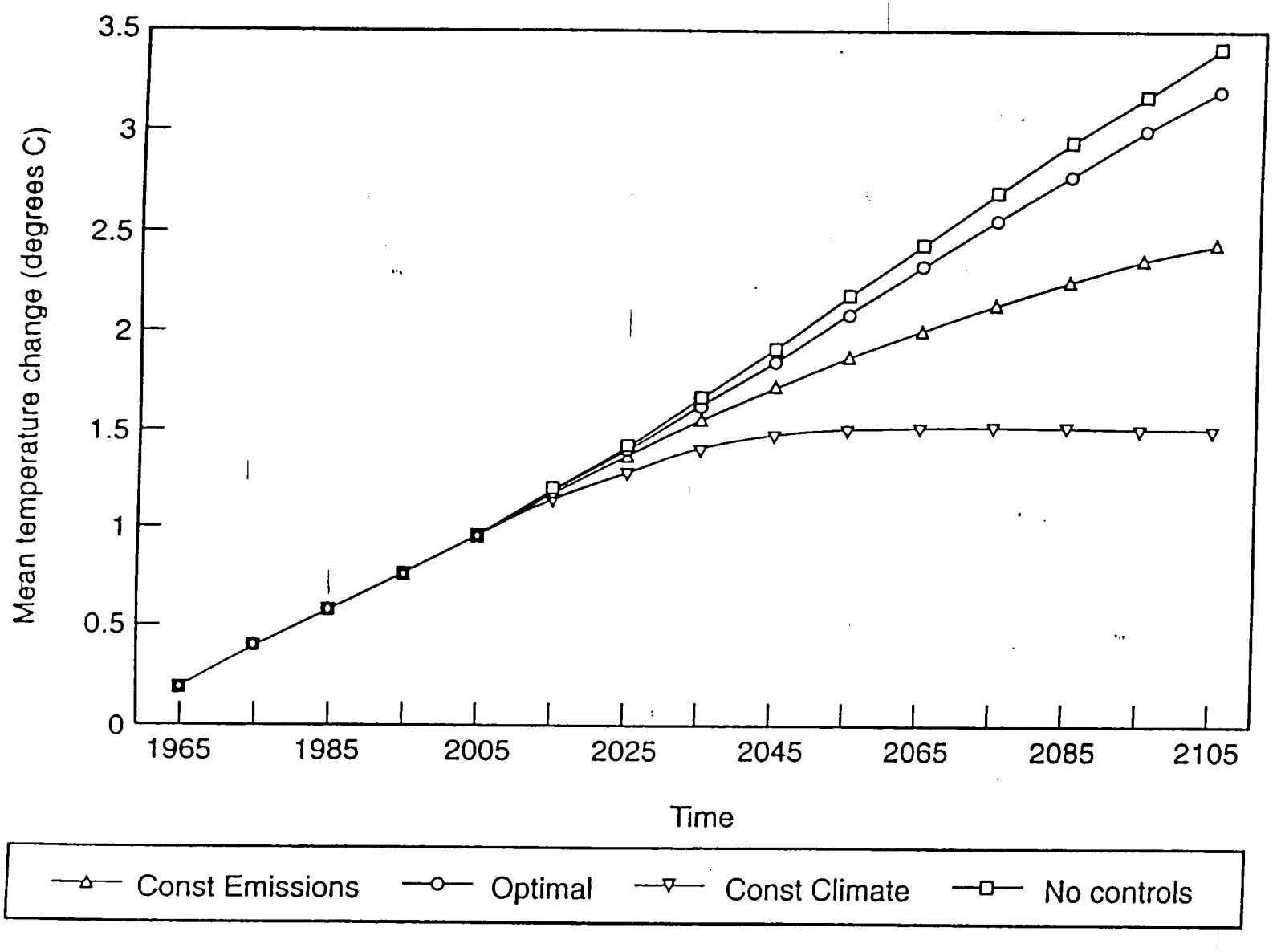


Figure 5.4
Global mean temperature
(Change from 1865)

Table 8.1 Effects of eliminating subsidies on commercial energy in Eastern Europe and the former U.S.S.R. and in developing countries

Effect	*Eastern Europe and former U.S.S.R.*	*Developing countries*
Reduction in emissions, 1995		
Amount (millions of tons of carbon)	446	234
As share of projected regional emissions (percent)	29	11
As share of projected global emissions (percent)	7	4
Cumulative reduction, 1991–2000		
Amount (millions of tons of carbon)	3,796	2,318
As share of projected cumulative regional emissions (percent)	24	11
As share of projected cumulative global emissions (percent)	6	4

Note: The base case is derived from World Bank projections of energy demand. In this scenario, worldwide carbon dioxide emissions increase by about 20 percent between 1990 and 2000.
Sources: World Bank staff estimates using Bates and Moore, background paper; Imran and Barnes 1990; Marland and others 1989; Hughes 1991.

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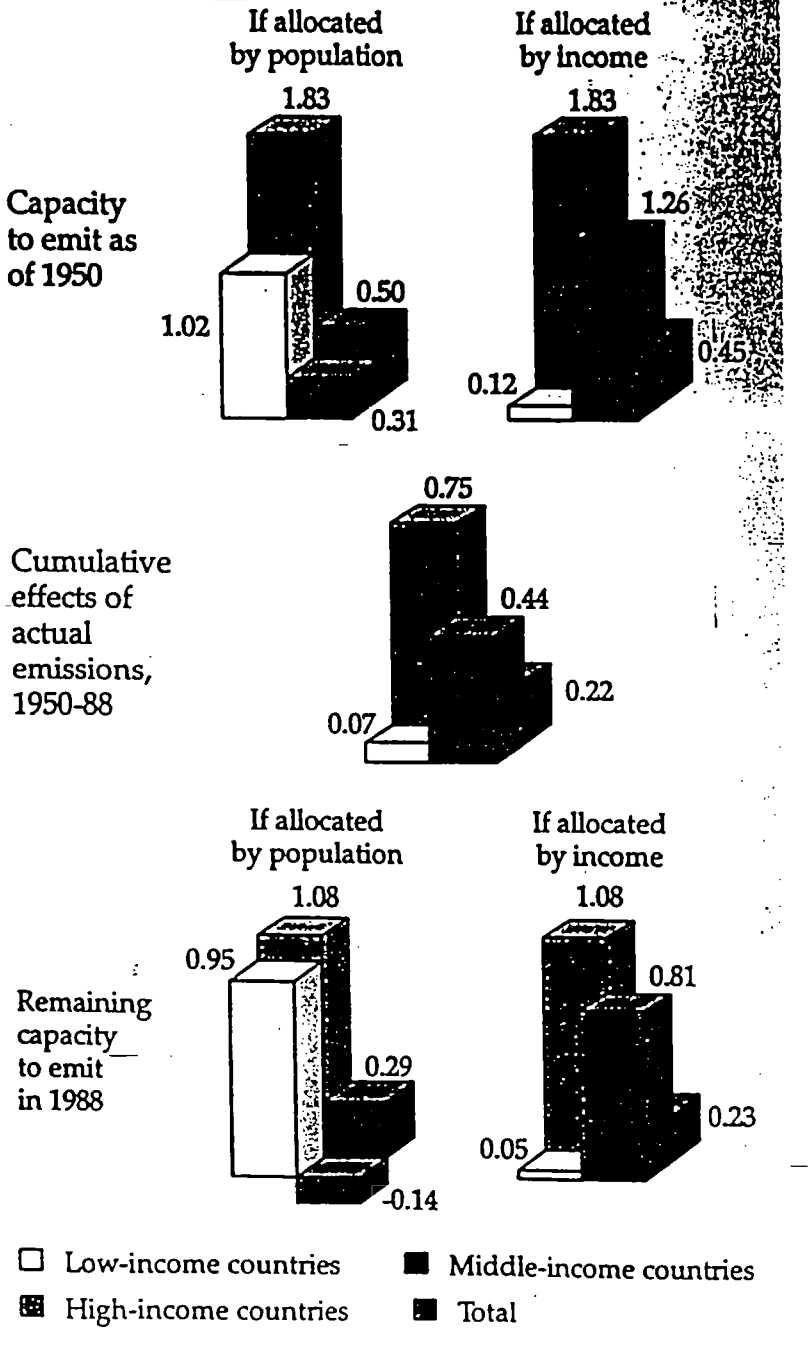
Figure 8.2 Scenarios for allocating capacity to emit carbon dioxide if greenhouse gas warming effect is stabilized at $2xCO_2$ *(warming effect of emissions in watts per square meter)*



Note: For illustrative purposes, it is assumed that the greenhouse gas warming effect is stabilized at the equivalent of double preindustrial carbon dioxide concentrations ($2xCO_2$). Actual emissions exclude deforestation due to lack of reliable data. 1950

PREFACE

Last year in Rio de Janeiro, Brazil, world leaders and citizens from more than 200 ountries came together to confront the global ecological crisis. The Earth Summit aroused the opes and dreams of people around the world and set in motion ambitious plans to address the lanet's deepest environmental threats. We shared a common mission: to provide a higher uality of life for ourselves and a brighter future for our children.

At the Earth Summit, the United States joined other countries in signing the Framework onvention on Climate Change, an international agreement to address the danger of global limate change. The Convention has been signed by 161 countries and has been ratified by 31 f those countries. The objective of the Convention was stated 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 should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food pro..uction is not threatened, and to enable economic development to proceed in a sustainable manner."*

The international community rallied around the threat of climate change because scientists ree that the risk is real. There is no doubt that human activities are increasing the atmospheric ncentrations of greenhouse gases, especially carbon dioxide, methane, and nitrous oxide. All

EXECUTIVE SUMMARY

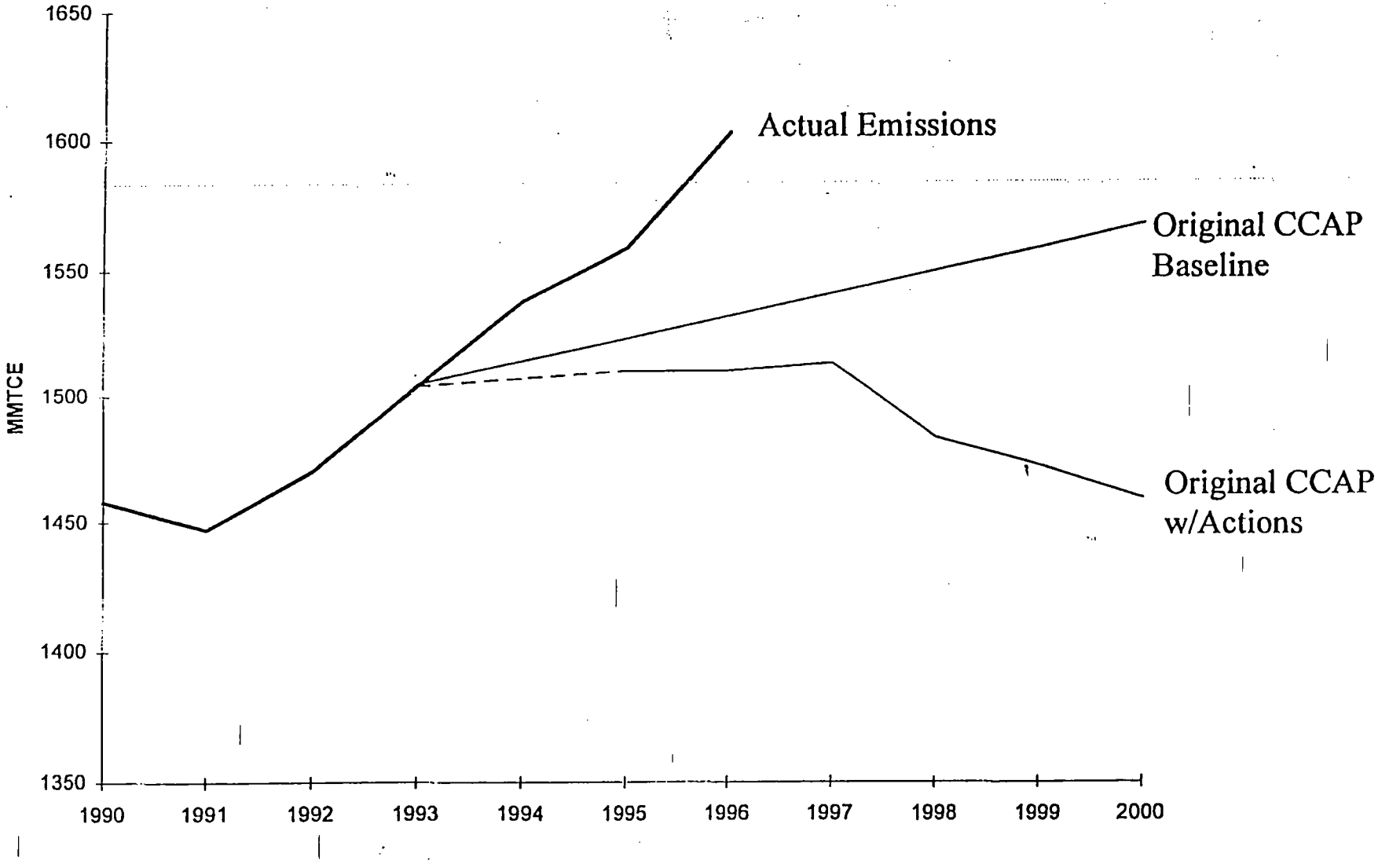
We must take the lead in addressing the challenge of global warming that could make our planet and its climate less hospitable and more hostile to human life. Today, I reaffirm my personal, and announce our nation's commitment to reducing our emissions of greenhouse gases to their 1990 levels by the year 2000. I am instructing my administration to produce a cost-effective plan ... that can continue the trend of reduced emissions. This must be a clarion call, not for more bureaucracy or regulation or unnecessary costs, but instead for American ingenuity and creativity, to produce the best and most energy-efficient technology.

President Clinton
April 21, 1993

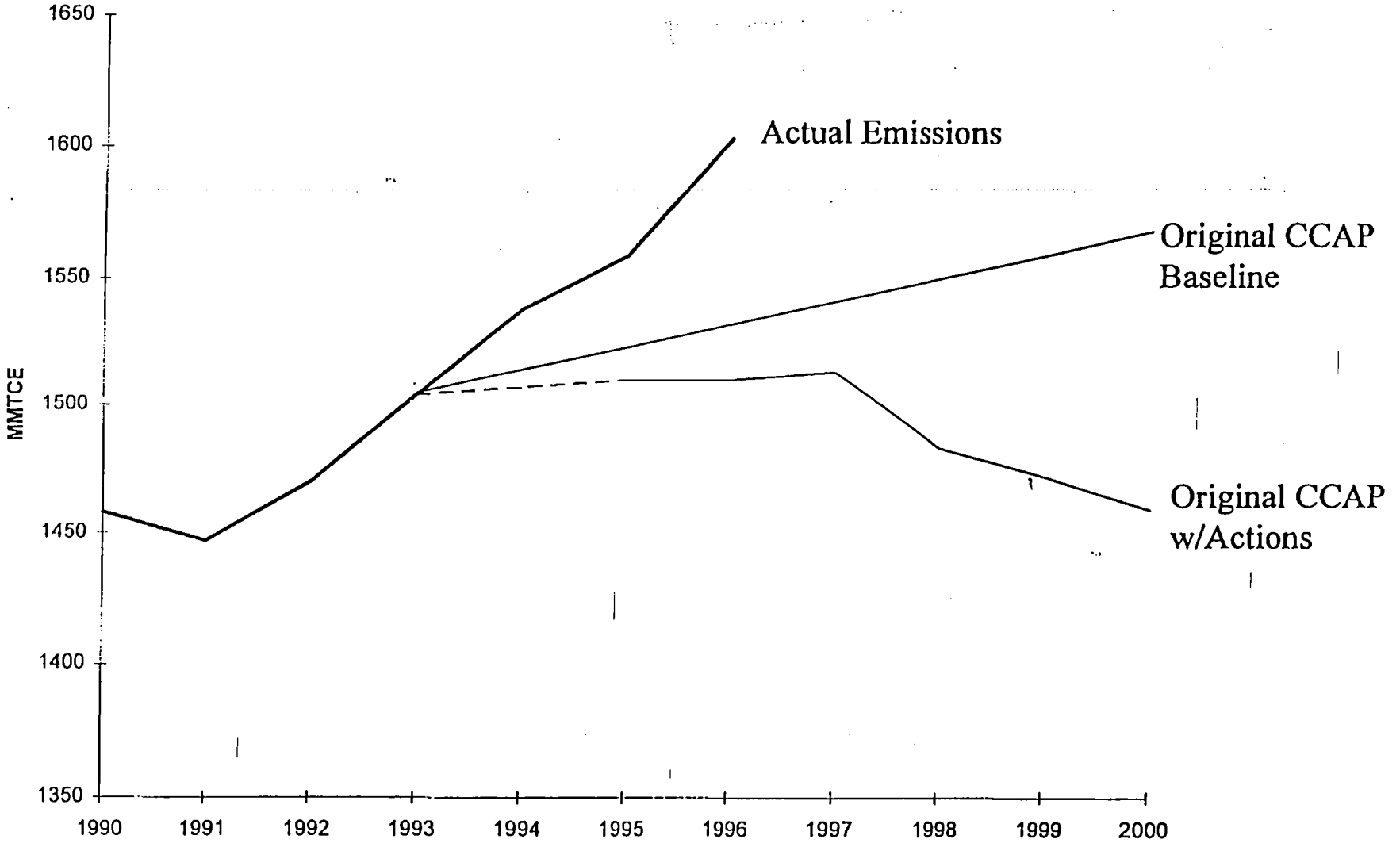
President Clinton's Climate Change Action Plan meets the twin challenges of responding to the threat of global warming and strengthening the economy. Returning U.S. greenhouse gas emissions to their 1990 levels by the year 2000 is an ambitious but achievable goal that can be attained while enhancing prospects for economic growth and job creation, and positioning our country to compete and win in the global market.

There is no doubt that human activity is increasing the concentration of greenhouse gases in the atmosphere. The buildup of greenhouse gases threatens to change the global climate system, raise sea levels and inundate coastal areas, inflict irreversible damage to ecosystems, and

US Greenhouse Gas Emissions: Original CCAP Projections and Actual through 1996



US Greenhouse Gas Emissions: Original CCAP Projections and Actual through 1996



congressional Hearings Testimony

CLIMATIC CHANGE: CAUSES, IMPACTS AND UNCERTAINTIES

Written Testimony of

Stephen H. Schneider
Professor, Department of Biological Sciences
Stanford University
Stanford, CA 94305

before

Committee on Environment and Public Works
U.S. Senate

Thursday, July 10, 1997, 9:30AM

I. Does Natural Variability Explain All Climate Change?

Twenty thousand years ago, a mere blink in geologic time, a visitor to the now-productive Corn Belt of Illinois would not be sitting in the heart of the world's foremost granary, but rather open spruce parkland forest, where many of the tree species seen are the same kinds that are found today 500 to 1,000 miles north in the Boreal Forests of Canada. Similarly, if we could somehow have been flying over the Great Basin we would have seen the massive fossil lakes, some stretching hundreds of miles like former Lake Bonneville in Utah, and the now-fossil beaches (currently visible flying into Salt Lake City Airport or over Mono Lake) from those high water stands that date back ten to fifteen thousand years ago. The Ice Age, which at its maximum some 20,000 years ago was about 5 ° to 7 °C (around 10^0F) colder than our current global climate, disappeared in, what is to nature, a relatively rapid period of about five to ten thousand years. The average rate of temperature change from the Ice Age to the current 10,000 year period of relative climate stability, our so-called Holocene Interglacial, is about 1 °C change for every thousand years. Of course there were more rapid periods embedded within this time frame, but I'm only giving the sustained average rates.

Not only did such change correspond with radical alterations to the ecosystems of the earth, but have been implicated in the extinction of what is known as the charismatic megafauna (woolly mammoth, saber tooth tigers, etc.). Fossil pollen evidence tells us that the vegetation habitats during the more "rapid" parts of the transition from ice age to interglacial around ten to twelve thousand years ago saw what paleoclimatologists call "no analog habitats," that is, combinations of pollen abundances which do not exist on earth today. All of this change was natural, of course, and there are two reasons for mentioning it in our context. First, to remind us that the climate and ecosystems change by themselves, without need of humans (the latter is what we call anthropogenic causation), and, two, that climate change of about several degrees on a global average basis is a very significant change from the point of view of natural systems.

Explanations of the Ice Age vary, the most popular one being a change in the amount of sunlight coming in between (a) winter and summer and (b) the poles and the equator. These changes in the distribution of seasonal or latitudinal sunshine are due to slow variations in the tilt of the earth's axis and other orbital elements, but these astronomical variations alone cannot totally explain the climatic cycles. If these orbital variations and other factors (such as the increased reflectivity of the earth associated with more ice) are combined, our best climate theories (embodied through mathematical models that are comprised of the physical laws of conservation of mass, energy and momentum) suggest that the Ice Age should have been several degrees warmer than it actually was -- especially in the Southern hemisphere. What could account for this extra cold? Perhaps the models are not sensitive enough, that is they do not respond sufficiently to a change in so called "radiative climate forcing," that is the change in the amount of radiant energy coming to the earth from external factors like orbital variations or extra ice. Another (more likely, I think) possibility is that something else also changed at the same time.

These theories can be better reconciled with what happened between ice ages and interglacials if one assumes that several watts of energy over every square meter of the earth were taken away in the ice age by some other mechanism at a global scale. But what could be such a mechanism? The obvious candidate would be a change in the composition of the earth's atmosphere which affects both its reflectivity and its heat trapping capacity (e.g. decreases in the well-known greenhouse effect or increases in atmospheric dust). But what evidence is there that greenhouse gases, for example carbon dioxide, methane, nitrous oxide, or water vapor, had lower concentrations 20,000 years ago than in the interglacial? About fifteen years ago that evidence came through loud and clear from the ice caps of the world. Air trapped in these glaciers provides a library of the history of the earth's atmosphere back some 200,000 years. It shows that during the past two ice ages carbon dioxide concentration was about 40% less and methane half of the average value during the current and penultimate interglacials. It also shows that since the Industrial Revolution carbon dioxide has increased beyond any levels experienced in the past 150,000 years (at least) by nearly 30% and methane by 150% -- two figures that virtually no knowledgeable scientist disputes are a result of so-called anthropogenic emissions which are driven by increasing numbers of people pursuing higher standards of living and using technology to achieve those growth-oriented goals.

If the carbon dioxide and methane decreases in the last ice age helped to explain the ice age coldness, can they tell us something about how the anthropogenic increase of these gases due to human activities might cause climate change in the future? The answer is "not directly," for it is possible that there are other factors we have not accounted for in the ice age story that could well have been involved, and there are still many unanswered questions associated with the Ice Age cycles. It is simply a circumstantial bit of evidence which suggests that it is more consistent to explain the ice ages with the heat trapping power of the greenhouse effect existing at the magnitudes currently envisioned by most scientists -- i.e. a doubling of CO_2 would raise surface temperatures by about 3 °C plus or minus 1.5 °C. This is known as the "climate sensitivity range." The magnitude of climate sensitivity that helps to explain the ice age coldness best is 2-3 °C. If the best estimate were ten degrees warming, which is twice the value at the high end of the climate sensitivity range thought by the mainstream of scientist today (e.g.. IPCC 1996a), then the ice ages should have been even colder than they were. On the other hand, if the earth would only warm up by half a degree or less if CO_2 doubled, then it would be tougher to explain the magnitude of the ice ages without finding some other mechanism not yet understood. Of course, the latter is possible, but what other lines of circumstantial evidence or direct evidence do we have for estimating climate sensitivity?

We know from quite literally thousands of laboratory experiments and direct measurements, millions of balloon observations and trillions of satellites data bits, that the basic structure of the energy flows in and out of the earth's atmosphere are relatively well understood. We know that water vapor, carbon dioxide, or methane trap enough energy on the earth to warm the surface up about 33 °C (60 °F) relative to that which would occur in their absence.

This well known natural greenhouse effect is not under dispute, and has been known for a century and a half. Nor is the 0.5 °C (plus or minus 0.2 °C) globally

averaged warming trend at the earth's surface over the past century in dispute. In dispute is whether a small increment since the Industrial Revolution in this envelope of greenhouse gases, which our calculations tell us should have trapped about two extra watts of energy over every square meter of Earth, would produce a noticeable response (i.e. a "climate signal"). The debate over whether that signal has been detected has been intense lately and this intensity has been based upon significant new pieces of evidence -- albeit each piece is circumstantial -- and a few loud, well-publicized denials that the totality of evidence has any meaning. In the absence of clear, direct empirical evidence, one often has to use either circumstantial evidence, or incomplete bits of direct evidence with uncertainties attached. When the preponderance of such evidence gets strong enough, then most scientists begin to accept, tentatively of course, the likelihood of causal connections. Some people shed their skepticism at different levels than others, so naturally there will be a cacophonous debate over whether a climate signal has been detected, let alone whether it could be attributed to human activities. One can always find some scientist who will want 999 out of a 1000 probability of certainty, and others who will accept the proposition at eight or nine chances out of ten. This is not science, but a value judgment about the acceptability of a significant, but not conclusive, body of evidence. The scientific job is to assess (A) what can happen, and (B) what the odds are of it happening (see, for example, this discussion in Chapter 6 of Schneider 1997a). Let me discuss this process further.

I have mentioned the ice ages since this is a "natural experiment" that we use, not to forecast the future, but to build understanding of climate processes and to validate the tools that we do use to forecast the future -- that is, our climate theories embodied in mathematical models. Are there any other such natural experiments? The answer is "yes there are many," the two most prominent being (1) episodic volcanic eruptions which throw dust in the stratosphere that reflects for a few years a few watts per square meter of solar energy that otherwise would have reached the lower atmosphere and (2) the seasonal cycle. Let's consider volcanic eruptions first. Volcanic dust veils should cool the planet. In fact, the last major eruption, Mt. Pinatubo in 1991, was forecast to cool the earth's lower atmosphere on the order of several tenths of a degree by a number of climate modeling groups -- in advance of the actual data to confirm -- and indeed, that is roughly what happened. However, it could be argued that a few tenths of a degree cooling, or warming for that matter, might be a natural fluctuation in the earth's climate system, and indeed, fluctuations of that magnitude are a part of the natural background "climatic noise." How then could we distinguish the climatic signal of the volcanic eruption from the noise of the natural variability? In any one eruption it is difficult to do so since the signal to noise ratio is about one, i.e. the magnitude of the cooling expected is about equal to the magnitude of the natural fluctuations in non-volcanic years, and therefore for any one event we cannot have very much confidence that a signal has been observed. So the fact that the Pinatubo results showed up about as predicted doesn't, by itself, give a lot of confidence, although as a circumstantial bit of evidence is quite useful. However, another volcanic eruption in 1983, El Chichón, was also followed by several tenths of a degree cooling, as was the effect after Mt. Agung in 1963 or Mt. Krakatoa in the Victorian period.

In other words, by looking at the results of several volcanic eruptions and compositing, a number of scientists (including Mass and Schneider, 1977) used this technique and discovered that indeed there was a clear and obvious correlation which suggests that when a few watts of energy over every square meter of the earth is removed by volcanic dust veils in the stratosphere, the lower atmosphere will indeed cool by a few tenths of degrees -- the very magnitude predicted by the same computer models that we use to forecast the effects of a few watts per square meter of sustained heating from global warming.

What other natural experiments might we have to test climate sensitivity? My favorite is one that happens every year -- the seasons. Winter predictably follows summer, being some fifteen degrees colder in the Northern Hemisphere and five degrees colder than summer in the Southern Hemisphere. The reason the Southern Hemisphere has a smaller seasonal cycle is because it has much more ocean than land, and water has a higher heat retaining capacity than land or air. Since a season is not long enough for the planet to reach an equilibrium temperature change, therefore, the more land dominated Northern Hemisphere has lower heat capacity and thus a larger seasonal cycle of surface temperature. How well do the climate models do in reproducing this change? The answer is "extraordinarily well." Although what the absolute temperatures models may simulate can be off by as much as five or six degrees in some regions of the world for some seasons, the models' capacity to reproduce the amplitude of the seasonal cycle of surface air temperatures, by and large, is quite good. (It is less good for other variables, however, particularly hydrological systems.) Now, if we were making a factor of ten error by either overestimating or underestimating the sensitivity of the climate to radiative forcing, it would be difficult for the models to reproduce the different seasonal cycle surface temperature amplitudes over land and oceans as well as they do. This is another piece of circumstantial evidence suggesting that current estimate of climate sensitivity is not off by a factor of ten, as some "contrarians" assert. Indeed, indirect evidence like ice ages, volcanic eruptions and the seasonal cycle simulation skills of models are prime reasons why many of us in the scientific community have for the past twenty years expected that "demonstrable" (e.g.. see p.11 of Schneider and Mesirow, 1976 -- in which I projected just such a change) anthropogenic climate change was not unlikely by the 21st century.

In summary, then, in my opinion it is unlikely that natural variability is the explanation of all climate change, especially that which has been documented in the 20th century. However, since much of the debate over detection and attribution of human-caused climate change hinges on the projections of climatic models, it is necessary to have at least a cursory understanding of how they work. Although it is impossible to treat more than the highlights of the nature and use of climatic models in a dozen pages, I nonetheless offer the following section in the hopes of reducing somewhat the confusion that may exist in many peoples' minds after listening to the often acrimonious and technically complex debate over climatic models and their credibility.

II. Overview Of Climate Modeling Fundamentals

Engineers and scientists build models -- either mathematical or physical ones -- primarily to perform tests that are either too dangerous, too expensive, or perhaps impossible to perform with the real thing. To simulate the climate, a modeler needs to decide which components of the climatic system to include and which variables to involve. For example, if we choose to simulate the long-term sequence of glacials and interglacials (the period between successive ice ages), our model needs to include explicitly the effects of all the important interacting components of the climate system operating over the past million years or so. These include the atmosphere, oceans, sea ice/glaciers (cryosphere), land surface (including biota), land sub-surface and chemical processes (including terrestrial and marine biogeochemical cycles), as well as the external or "boundary forcing" conditions such as input of solar radiant energy (e.g., see IPCC, 1996a).

The problem for earth systems scientists is separating out quantitatively cause and effect linkages from among the many factors that interact within the earth system. It is a controversial effort because there are so many sub-systems, so many forcings and so many interacting complex sets of processes operating at the same time that debates about the adequacy of models often erupt.

Modeling the Climate System. So how are climate models constructed? First, scientists look at observations of changes in temperatures, ozone levels and so forth. This allows us to identify correlations among variables. Correlation is not necessarily cause and effect -- just because one event tracks another doesn't mean it was caused by it. One has to actually prove the relationship is causal and explain how it happened. Especially for cases where unprecedented events are being considered, a first principles, rather than a purely empirical-statistical approach is desirable. However, observations can lead to a hypothesis of cause and effect -- "laws" -- that can be tested (for example, see Root and Schneider, 1995). The testing is often based on simulations with mathematical models run on a computer. The models, in turn, need to be tested against a variety of observations -- present and paleoclimatic. That is how the scientific method is typically applied. When a model, or set of linked models, appear plausible, they can be fed "unprecedented" changes such as projected human global change forcings -- changes that have not happened before -- and then be asked to make projections of future climate, ozone levels, forests, species extinction rates, etc.

The most comprehensive weather simulation models produce three dimensional details of temperature, winds, humidity, and rainfall all over the globe. A weather map generated by such a computer model -- known as a general circulation model or GCM -- often looks quite realistic, but it is never faithful in every detail. To make a weather map generated by computer we need to solve six partial differential equations that describe the fluid motions in the atmosphere. It sounds in principle like there's no problem: we know that those equations work in the laboratory, we know that they describe fluid motions and energy and mass relationships. So why then aren't the models perfect simulations of the atmospheric behavior?

One answer is that the evolution of weather from some starting weather map (known as the initial condition) is not deterministic beyond about 10 days -- even in principle. A weather event on one day cannot be said to determine an event 20 days in the future, all those commercial "long-range" weather forecasts notwithstanding. But the inherent unpredictability of weather details much beyond ten days (owing to the chaotic internal dynamics of the atmosphere) doesn't preclude accurate forecasts of long-term averages (climate rather than weather). The seasonal cycle is absolute proof of such deterministic predictability, as winter reliably follows summer and the cause and effect is known with certainty.

Grids and Parameterization. The other answer to the imperfection of general circulation model simulations, even for long-term averages, is that nobody knows how to solve those six complex mathematical equations exactly. It's not like an algebraic equation where one can get the exact solution by a series of simple operations. There isn't any known mathematical technique to solve such coupled, nonlinear partial differential equations exactly. We approximate the solutions by taking the equations, which are continuous, and breaking them down into discrete chunks which we call grid boxes. A typical GCM grid size for a "low resolution" model is about the size of Colorado horizontally and that of a "high resolution" GCM is about the size of Connecticut. In the vertical dimension there are two (low resolution) up to about twenty (high resolution) vertical layers that are typically spanning the lowest 10 to 40 kilometers of the atmosphere.

Now, we've already noted that clouds are very important to the energy balance of the earth-atmosphere system since they reflect sunlight away and trap infrared heat. But because none of us have ever seen a single cloud the size of Connecticut, let alone Colorado, we have a problem of scale -- how can we treat processes that occur in nature at a smaller scale than we can resolve by our approximation technique of using large grid boxes. For example, we cannot calculate clouds explicitly because individual clouds are typically the size of a dot in this grid box. But we can put forward a few reasonable propositions on cloud physics: if it's a humid day, for example, it's more likely to be cloudy. If the air is rising, it's also more likely to be cloudy.

These climate models can predict the average humidity in the gridbox, and whether the air is rising or sinking on average. So then we can write what we call a parametric representation or "parameterization" to connect large scale variables that are resolved by the grid box (such as humidity) to unresolved small scale processes (individual clouds). Then we get a prediction of grid box-averaged cloudiness through this parameterization. So-called "cumulus parameterization" is one of the important -- and controversial --elements of GCMs that occupy a great deal of effort in the climate modeling community. Therefore, the models are not ignoring cloudiness, but neither are they explicitly resolving individual clouds. Instead, modelers try to get the average effect of processes that can't be resolved explicitly at smaller scales than the smallest resolved scale (the grid box) in the GCM. Developing, testing and validating many such parameterizations is the most important task of the modelers since these parameterizations determine critically important issues like "climate sensitivity." The climate sensitivity is the degree of response of the climate system to a unit change in

some forcing factor: typically, in our context, the change in globally-averaged surface air temperature to a fixed doubling of the concentration of atmospheric carbon dioxide above pre-industrial levels. This brings us to one of the most profound controversies in earth systems science, and one of the best examples of the usefulness, and fragility, of computer modeling.

The Greenhouse Effect. If the earth only absorbed radiation from the sun without giving an equal amount of heat back to space by some means, the planet would continue to warm up until the oceans boiled. We know the oceans are not boiling, and surface thermometers plus satellites have shown that the earth's temperature remains roughly constant from year to year (the interannual globally-averaged variability of about 0.2 °C or the 0.5 °C warming trend in the 20th century, notwithstanding). This near constancy requires that about as much radiant energy leaves the planet each year in some form as is coming in. In other words, a near-equilibrium or energy balance has been established. The components of this energy balance are crucial to the climate.

All bodies with temperature give off radiant energy. The earth gives off a total amount of radiant energy equivalent to that of a black body -- a fictional structure that represents an ideal radiator -- with a temperature of roughly -18 °C (255 °K). The mean global surface air temperature is about 14 °C (287 °K), some 32 °C warmer than the earth's black body temperature. The difference is due to the well-established greenhouse effect.

The term greenhouse effect arises from the classic analogy to a greenhouse, in which the glass allows the solar radiation in and traps much of the heat inside. However, the mechanisms are different, for in a greenhouse the glass primarily prevents convection currents of air from taking heat away from the interior. Greenhouse glass is not primarily keeping the enclosure warm by its blocking or re-radiating infrared radiation; rather, it is constraining the physical transport of heat by air motion.

Although most of the earth's surface and thick clouds are reasonably close approximations to a black body, the atmospheric gases are not. When the nearly black body radiation emitted by the earth's surface travels upward into the atmosphere, it encounters air molecules and aerosol particles. Water vapor, carbon dioxide, methane, nitrous oxide, ozone, and many other trace gases in the earth's gaseous envelope tend to be highly selective -- but often highly effective -- absorbers of terrestrial infrared radiation. Furthermore, clouds (except for thin cirrus) absorb nearly all the infrared radiation that hits them, and then they reradiate energy almost like a black body at the temperature of the cloud surface -- colder than the earth's surface most of the time.

The atmosphere is more opaque to terrestrial infrared radiation than it is to incoming solar radiation, simply because the physical properties of atmospheric molecules, cloud and dust particles tend on average to be more transparent to solar radiation wavelengths than to terrestrial radiation. These properties create the large surface heating that characterizes the greenhouse effect, by means of which the atmosphere allows a considerable fraction of solar radiation to penetrate to the earth's surface and then traps (more precisely, intercepts and re-radiates) much of the upward terrestrial infrared radiation from the surface and lower atmosphere. The downward re-

radiation further enhances surface warming and is the prime process causing the greenhouse effect.

This is not a speculative theory, but a well understood and validated phenomenon of nature. The most important greenhouse gas is water vapor, since it absorbs terrestrial radiation over most of the infrared spectrum. Even though humans are not altering the average amount of water vapor in the atmosphere very much by direct injections of this gas, increases in other greenhouse gases which warm the surface cause an increase in evaporation which increases atmospheric water vapor concentrations, leading to an amplifying or "positive" feedback process known as the "water vapor-surface temperature-greenhouse feedback." The latter is believed responsible for the bulk of the climate sensitivity (IPCC, 1996a). Carbon dioxide is another major greenhouse gas. Although it absorbs and re-emits considerably less infrared radiation than water vapor, CO_2 is of intense interest because its concentration is increasing due to human activities. Ozone, nitrogen oxides, some hydrocarbons, and even some artificial compounds like chlorofluorocarbons are also greenhouse gases. The extent to which they are important to climate depends upon their atmospheric concentrations, the rates of change of those concentrations and their effects on depletion of stratospheric ozone --which in turn, can indirectly modify the radiative forcing of the lower atmosphere thus changing climate -- currently offsetting a considerable fraction of the otherwise expected greenhouse warming signal.

The earth's temperature, then, is primarily determined by the planetary radiation balance, through which the absorbed portion of the incoming solar radiation is nearly exactly balanced over a year's time by the outgoing terrestrial infrared radiation emitted by the climatic system to earth. As both of these quantities are determined by the properties of the atmosphere and the earth's surface, major climate theories that address changes in those properties have been constructed. Many of these remain plausible hypotheses of climatic change. Certainly *the natural greenhouse effect is established beyond a reasonable scientific doubt*, accounting for natural warming that has allowed the coevolution of climate and life to proceed to this point (e.g., see Schneider and Londer, 1984). The extent to which human augmentation of the natural greenhouse effect (i.e., global warming) will prove serious is, of course, the current debate.

Model Validation. There are many types of parameterizations of processes that occur at a smaller scale than our models can resolve, and scientists debate which type is best. In effect, are they an accurate representation of the large-scale consequences of processes that occur on smaller scales than we can explicitly treat? These include cloudiness, radiative energy transport, turbulent convection, evapotranspiration, oceanic mixing processes, chemical processes, ecosystem processes, sea ice dynamics, precipitation, mountain effects and surface winds.

In forecasting climatic change, then, validation of the model becomes important. In fact, we can not easily know in principle whether these parameterizations are "good enough." We have to test them in a laboratory. That's where the study of paleoclimates has proved so valuable (e.g., Hoffert and Covey, 1992). We also can test parameterizations by undertaking detailed small-scale field or modeling studies aimed at

understanding the high resolution details of some parameterized process the large-scale model has told us is important. The Second Assessment Report of IPCC (IPCC, 1996a) Working Group I devoted more than one chapter to the issue of validation of climatic models, concluding that "the most powerful tools available with which to assess future climate are coupled climate models, which include three-dimensional representations of the atmosphere, ocean, cryosphere and land surface. Coupled climate modeling has developed rapidly since 1990, and current models are now able to simulate many aspects of the observed climate with a useful level of skill. [For example, as noted earlier, good skill is found in simulating the very large annual cycle of surface temperatures in Northern and Southern Hemispheres or the cooling of the lower atmosphere following the injection of massive amounts of dust into the stratosphere after explosive volcanic eruptions such as Mt. Pinatubo in the Philippines in 1991.] Coupled model simulations are most accurate at large spatial scales (e.g., hemispheric or continental); at regional scales skill is lower". [sentence in square brackets added]

One difficulty with coupled models is known as "flux adjustment"-- a technique for accounting for local oceanic heat transport processes that are not well simulated in some models. Adding this element of empirical-statistical "tuning" to models that strive to be based as much as possible on first principles has been controversial. However, not all models use flux adjustments, yet nearly all models, with or with out this technique, produce climate sensitivities within or near to the standard IPCC range of 1.5 to 4.5 °C. Flux adjustments do, however, have a large influence on regional climatic projections, even if they prove not to be a major impact on globally-averaged climate sensitivity. Improving coupled models is thus a high priority for climate researchers since it is precisely such regional projections that are so critical to the assessment of climatic impacts on environment and society (e.g., IPCC, 1996b; IPCC, 1997).

Transient versus Equilibrium Simulations. One final issue needs to be addressed in the context of coupled climate simulations. Until recently, climate modeling groups did not have access to sufficient computing power to routinely calculate time evolving runs of climatic change given several alternative future histories of greenhouse gases and aerosol concentrations. That is, they did not perform so-called transient climate change scenarios. (Of course, the real Earth is undergoing a transient experiment.) Rather, the models typically were asked to estimate how the Earth's climate would eventually be altered (i.e., in equilibrium) after CO_2 was artificially doubled and held fixed indefinitely rather than increased incrementally over time as it has in reality or in more realistic transient model scenarios. The equilibrium climate sensitivity has remained fairly constant for over twenty years of assessments by various national and international groups, with the assessment teams repeatedly suggesting that, were CO_2 to double, climate would eventually warm at the surface somewhere between 1.5 and 4.5 °C. (Later on we will address the issue of the probability that warming above or below this range might occur, and how probabilities can even be assigned to this sensitivity.)

Transient model simulations exhibit less immediate warming than equilibrium simulations because of the high heat holding capacity of the thermally massive oceans. However, that unrealized warming eventually expresses itself decades to centuries later.

This thermal delay, which can lull us into underestimating the long-term amount of climate change, is now being accounted for by coupling models of the atmosphere to models of the oceans, ice, soils, and biosphere (so-called earth system models -- ESMs). Early generations of such transient calculations with ESMs give much better agreement with observed climate changes on Earth than previous calculations in which equilibrium responses to CO_2 doubling were the prime simulations available. When the transient models at the Hadley Center in the United Kingdom and the Max Planck Institute in Hamburg, Germany were also driven by both greenhouse gases (which heat) and sulfate aerosols (which cool), these time evolving simulations yielded much more realistic "fingerprints" of human effects on climate(e.g., Chapter 8 of IPCC, 1996a). More such computer simulations are needed to provide high confidence levels in the models, but scientists using coupled, transient simulations are now beginning to express growing confidence that current projections are plausible.

Transients and Surprises. However, such a very complicated coupled system like an ESM is likely to have unanticipated results when forced to change very rapidly by external disturbances like CO_2 and aerosols. Indeed, some of the transient models run out for hundreds of years exhibit dramatic change to the basic climate state (e.g., radical change in global ocean currents). Thompson and Schneider (1982) used very simplified transient models to investigate the question of whether the time evolving patterns of climate change might depend on the rate at which CO_2 concentrations increased. For slowly increasing CO_2 buildup scenarios, the model predicted the standard model outcome: the temperature at the poles warmed more than the tropics.

Any changes in equator-to-pole temperature difference help to create altered regional climates, since temperature differences over space influence large-scale atmospheric wind patterns. However, for very rapid increases in CO_2 concentrations a reversal of the equator-to-pole difference occurred. If sustained over time, this would imply difficult to forecast, transient climatic conditions during the century or so the climate adjusts toward its new equilibrium state. In other words, the harder and faster the enormously complex earth system is forced to change, the higher the likelihood for unanticipated responses. Or, in a phrase, *the faster and harder we push on nature, the greater the chances for surprises* -- some of which are likely to be nasty.

Noting this possibility, the Summary for Policy makers of IPCC Working Group I concluded with the following paragraph:

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

Of course, if the Earth system were somehow less "rapidly forced" by virtue of policies designed to slow down the rate at which human activities modify the land surfaces and atmospheric composition, this would lower the likelihood of non-linear surprises. Whether the risks of such surprises justify investments in abatement activities is the question that Integrated Assessment (IA) activities are designed to inform (IPCC, 1996c). The likelihood of various climatic changes, along with estimates of the probabilities of such potential changes, are the kinds of information IA modelers need from earth systems scientists in order to perform IA simulations. We turn next, therefore, to a discussion of methods to evaluate the subjective probability distributions of scientists on one important climate change issue, the climate sensitivity.

Subjective Probability Estimation. Finally, what does define a scientific consensus? Morgan and Keith (1995) and Nordhaus (1994) are two attempts by non-climate scientists, who are interested in the policy implications of climate science, to tap the knowledgeable opinions of what they believe to be representative groups of scientists from physical, biological and social sciences on two separate questions: first the climate science itself and second impact assessment and policy. Their sample surveys show that although there is a wide divergence of opinion, nearly all scientists assign some probability of negligible outcomes and some probability of very highly serious outcomes, with one or two exceptions, like Richard Lindzen at MIT (who is scientist number 5 on Fig. 1 of Morgan and Keith).

In the Morgan and Keith study, each of the 16 scientists listed in Table 1 were put through a several hour, formal decision-analytic elicitation of their subjective probability estimates for a number of factors. Figure 1 shows the elicitation results for the important climate sensitivity factor. Note that 15 out of 16 scientists surveyed (including several IPCC Working Group I Lead Authors -- I am scientist 9) assigned something like a 10% subjective likelihood of negligible (less than 1 °C) climatic change from doubling of CO_2. These scientists also typically assigned a 10% probability for extremely large climatic changes --greater than 5 °C, roughly equivalent to the temperature difference experienced between a glacial and interglacial age, but occurring some hundred times more rapidly. In addition to the lower probabilities assigned to the mild and catastrophic outcomes, the bulk of the scientists interviewed (with the one exception) assigned the bulk of their subjective cumulative probability distributions in the center of the IPCC range for climate sensitivity. What is most striking about the exception, scientist 5, is the lack of variance in his estimates--suggesting a very high confidence level in this scientist's mind that he understands how all the complex interactions within the earth-system described above will work. None of the other scientists displayed that confidence, nor did the Lead Authors of IPCC. However, several scientists interviewed by Morgan and Keith expressed concern for "surprise" scenarios -- for example, scientists 2 and 4 explicitly display this possibility on Figure 1, whereas several other scientists implicitly allow for both positive and negative surprises since they assigned a considerable amount of their cumulative subjective probabilities for climate sensitivity outside of the standard 1.5 to

4.5 range. This concern for surprises is consistent with the concluding paragraph of the IPCC Working Group I Summary for Policymakers quoted above.

IPCC Lead Authors, who wrote the Working Group I Second Assessment Report, were fully aware of both the wide range of possible outcomes and the broad distributions of attendant subjective probabilities. After a number of sentences highlighting such uncertainties, the Report concluded: "nevertheless, the balance of evidence suggests that there is a discernible human influence on the climate." The reasons for this now-famous subjective judgment were many, such as the kinds of factors listed above. These include a well validated theoretical case for the greenhouse effect, validation tests of both model parameterizations and performance against present and paleoclimatic data, and the growing "fingerprint" evidence that suggests horizontal and vertical patterns of climate change predicted to occur in coupled atmosphere-ocean models has been increasingly evident in observations over that past several decades. Clearly, more research is needed, but enough is already known to warrant assessments of the possible impacts of such projected climatic changes and the relative merits of alternative actions to both mitigate emissions and/or make adaptations less costly. That is the ongoing task of integrated assessment analysts, a task that will become increasingly critical in the next century. To accomplish this task, it is important to recognize what is well established in climate theory and modeling and to separate this from aspect that are more speculative. That is precisely what IPCC (1996a) has attempted to accomplish.

III. Assessing The Impacts Of Climatic Change Projections

One of the most dramatic of the standard "impacts" of climatic warming projections is the increase in sea level typically associated with warmer climatic conditions. An EPA study used an unusual approach: combining climatic models with the subjective opinions of many scientists on the values of uncertain elements in the models to help bracket the uncertainties inherent in this issue. Titus and Narayanan (1996) -- including teams of experts of all persuasions on the issue -- calculated the final product of their impact assessment as a statistical distribution of future sea level rise, ranging from slightly negative values (i.e., a sea level drop) as a low probability outcome, to a meter or more rise, also with a low probability (see Fig 2). The midpoint of the probability distribution is something like half meter sea level rise by the end of the next century.

Since the EPA analysis stopped there, this is by no means a complete assessment. In order to take integrated assessment to its logical conclusion, we need to ask what the economic costs of various control strategies might be and how the costs of abatement compare to the economic or environmental losses (i.e. impacts or damages as they are called) from sea level rises. That means putting a value -- a dollar value of course -- on climate change, coastal wetlands, fisheries, environmental refugees, etc. Hadi Dowlatabadi at Carnegie Mellon University leads a team of integrated assessors who, like Titus, combined a wide range of scenarios of climatic changes and impacts but, unlike the EPA studies, added a wide range of abatement cost estimates into the mix. Their integrated assessment was presented in statistical form as a probability that investments

in CO_2 emissions controls would either cost more than the losses from averted climate change or the reverse (e.g., Morgan and Dowlatabadi, 1996). Since their results do not include estimates for all conceivable costs (e.g., the political consequences of persons displaced from coastal flooding), the Carnegie Mellon group offered its results only as illustrative of the capability of integrated assessment techniques. Its numerical results have meaning only after the range of physical, biological and social outcomes and their costs and benefits have been quantified -- a Herculean task. Similar studies have been made in Holland by a Dutch government effort to produce integrated assessments for policy makers. Jan Rotmans, who heads one of their efforts, likes to point out that such modeling of complex physical, biological and social factors cannot produce credible "answers" to current policy dilemmas, but can provide "insights" to policy makers that will put decision-making on a firmer factual basis (Rotmans and van Asselt, 1996). Understanding the strengths and weaknesses of any complex analytic tool is essential to rational policy making, even if quantifying the costs and benefits of specific activities is controversial.

William Nordhaus, an economist from Yale University, has made heroic steps to put the climatic change policy debate into an optimizing framework. He is an economist who has long acknowledged that an efficient economy must internalize externalities (in other words, find the full social costs of our activities, not just the direct cost reflected in conventional "free market" prices). He tried to quantify this external damage from climate change and then tried to balance it against the costs to the global economy of policies designed to reduce CO_2 emissions. His optimized solution was a carbon tax, designed to internalize the externality of damage to the climate by increasing the price of fuels in proportion to how much carbon they emit, thereby providing an incentive for society to use less of these fuels.

Nordhaus (1992) imposed carbon tax scenarios ranging from a few dollars per ton to hundreds of dollars per ton -- the latter which would effectively eliminate coal from the world economy. He showed that, in the context of his model and its assumptions, that these carbon emission fees would cost the world economy anywhere from less than 1 percent annual loss in Gross National Product to a several percent loss by the year 2100. The efficient, optimized solution from classical economic cost-benefit analysis is that carbon taxes should be levied sufficient to reduce the GNP as much as it is worth to avert climate change (e.g. the damage to GNP from climate change). He assumed that the impacts of climate change were equivalent to a loss of about one percent of GNP. This led to an "optimized" initial carbon tax of about five dollars or so per ton of carbon dioxide emitted. In the context of his modeling exercise, this would avert only a few tenths of a degree of global warming to the year 2100, a very small fraction of the 4 °C warming his model projected.

How did Nordhaus arrive at climate damage being about 1 percent of GNP? He assumed that agriculture was the most vulnerable economic market sector to climate change. For decades agronomists had calculated potential changes to crop yields from various climate change scenarios, suggesting some regions now too hot would sustain heavy losses from warming whereas others, now too cold, could gain. Noting that the US lost about one third of it's agricultural economy in the heat waves of 1988, and that

agriculture then represented about 3 % of the US GNP, Nordhaus felt the typically-projected climatic changes might thus cost the U.S. economy something like 1% annually in the 21st century. This figure was severely criticized because it neglected damages from health impacts (e.g., expanded areas of tropical diseases, heat-stress deaths, etc.), losses from coastal flooding or severe storms, security risks from boat people created from coastal disruptions in South Asia or any damages to wildlife, fisheries or ecosystems that would almost surely accompany temperature rises at rates of degrees per century as are typically projected. It also was criticized because his estimate neglected potential increases in crop or forestry yields from the direct effects of increased CO_2 in the air on the photosynthetic response of these marketable plants. Nordhaus responded to his critics by conducting a survey, similar to that undertaken by Morgan and Keith, but this time focused on the impacts of several scenarios of climatic change on world economic product -- including both standard market sector categories (e.g., forestry, agriculture, heating and cooling demands) and so-called non-market amenities like biological conservation and national security.

When Nordhaus surveyed the opinions of mainstream economists, environmental economists and natural scientists (I am respondent #10, in Nordhaus, 1994), he found that the former expressed a factor of twenty less anxiety about the economic or environmental consequences of climate change than the latter (see Fig.3 -- Scenario A is for 3 °C warming by 2100 A.D. and Scenario C for 6 °C by 2100 A.D.). However, the bulk of even the conservative group of economists Nordhaus surveyed considered there to be at least a ten percent probability that typically projected climate changes could still cause economic damages worth several percent of gross world product (the current US GNP is around five trillion dollars -- about twenty percent of the global figure). And, some of these economists didn't include estimates for possible costs of "non-market" damages (e.g., harm to nature). One ecologist who did explicitly factor in non-market values for natural systems went so far as to assign a ten percent chance of a hundred percent loss of GNP -- the virtual end of civilization! While Nordhaus quipped that those who know most about the economy are less concerned, I countered with the obvious observation that those who know the most about nature are very concerned.

We will not easily resolve the paradigm gulf between the optimistic and pessimistic views of these specialists with different training, traditions and world views, but the one thing that is clear from both the Morgan and Keith and Nordhaus studies is that the vast bulk of knowledgeable experts from a variety of fields admits to a wide range of plausible outcomes in the area of global environmental change -- including both mild and catastrophic eventualities -- under their broad umbrella of possibilities. This is a condition ripe for misinterpretation by those who are unfamiliar with the wide range of probabilities most scientists attach to global change issues. The wide range of probabilities follows from recognition of the many uncertainties in data and assumptions still inherent in earth systems models, climatic impact models, economic models or their synthesis via integrated assessment models (see Schneider, 1997a,b). It is necessary in a highly interdisciplinary enterprise like the integrated assessment of global change problems that a wide range of possible outcomes be included, along with a representative sample of the subjective probabilities that knowledgeable assessment groups like the

IPCC believe accompany each of those possible outcomes. In essence, the "bottom line" of estimating climatic impacts is that both "the end of the world" and "it is good for business" are the two lowest probability outcomes, and that the vast bulk of knowledgeable scientists and economists consider there to be a significant chance of climatic damage to both natural and social systems. Under these conditions -- and the unlikelihood that research will soon eliminate the large uncertainties that still persist -- it is not surprising that most formal climatic impact assessments have called for cautious, but positive steps both to slow down the rate at which humans modify the climatic system and to make natural and social systems more resilient to whatever changes do eventually materialize.

IV. Policy Implications

What Are Some Actions to Consider? Decision making, of course, is a value judgment about how to take risks -- gambling, if you will -- in the environment-development arena. Despite the often bewildering complexity, making value choices does not require a Ph.D. in statistics, political science or geography to comprehend. Rather, citizens need simple explanations using common metaphors and everyday language that ordinary people can understand about the terms of the debate. Once the citizens of this planet become aware of the various tradeoffs involved in trying to choose between business-as-usual activities and sustainable environmental stewardship, the better will be the chances that the risk-averse common sense of the "average" person may be thrust into the decision-making process by a public that cares about its future and that of its planet, and knows enough not to be fooled by simple solutions packaged in slick commercials or editorials by any special interest.

What are the kinds of actions that can be considered to deal with global change problems like climate change. The following list is a consensus from a multi-disciplinary, business, university and government assessment conducted by the National Research Council in 1991. It is encouraging that this multi-discipline, ideologically diverse group (including economist Nordhaus, industrialist Frosch and climatologist Schneider) could agree that the United States, for example, could reduce or offset its greenhouse gas emissions by between 10 and 40 percent of 1990 levels at low cost, or at some net savings, if proper policies are implemented. Here is the Council's entire suggested list:

(1) Continue the aggressive phaseout of CFC and other halocarbon emissions and the development of substitutes that minimize or eliminate greenhouse gas emissions.
(2) Study in detail the "full social cost pricing" of energy, with a goal of gradually introducing such a system. On the basis of the principle that the polluter should pay, pricing of energy production and use should reflect the full costs of the associated environmental problems.
(3) Reduce the emissions of greenhouse gases during energy use and consumption by enhancing conservation and efficiency.
(4) Make greenhouse warming a key factor in planning for our future energy supply mix. The United States should adopt a systems approach that considers the interactions among

supply, conversion, end use, and external effects in improving the economics and performance of the overall energy system.
(5) Reduce global deforestation.
(6) Explore a moderate domestic reforestation program and support international reforestation efforts.
(7) Maintain basic, applied, and experimental agricultural research to help farmers and commerce adapt to climate change and thus ensure ample food.
(8) Make water supply more robust by coping with present variability by increasing efficiency of use through water markets and by better management of present systems of supply.
(9) Plan margins of safety for long-lived structures to take into consideration possible climate change.
(10) Move to slow present losses in biodiversity.
(11) Undertake research and development projects to improve our understanding of both the potential of geoengineering options to offset global warming and their possible side-effects. This is not a recommendation that geoengineering options be undertaken at this time, but rather that we learn more about their likely advantages and disadvantages.
(12) Control of population growth has the potential to make a major contribution to raising living standards and to easing environmental problems like greenhouse warming. The United States should resume full participation in international programs to slow population growth and should contribute its share to their financial and other support.
(13) The United States should participate fully with officials at an appropriate level in international agreements and in programs to address greenhouse warming, including diplomatic conventions and research and development efforts.

This NRC (1991) assessment produced a remarkable list, considering the diversity of the participants' backgrounds and their varying ideological perspectives. But in the crucible of open debate that permeated that assessment activity, self-interest polemics and media grandstanding are incinerated. This group didn't assert that catastrophe was inevitable, nor that it was improbable. We simply believed that prudence dictates that "despite the great uncertainties, greenhouse warming is a potential threat sufficient to justify action now."
Integrated assessments of the policy options offered by the National Research Council Report are actively being pursued with a variety of models.

It is interesting that this comprehensive list of 13 recommendations from the National Research Council report still ignored two fundamental aspects: the desperate need for (1) an intelligent, non-polemical public debate about global change and (2) interdisciplinary public education that also teaches students about whole systems and long-term risk management, not only traditional areas of isolated specialization.

Environment and (or versus) Development? While the NRC report did acknowledge the importance of international dimensions of global change policy making, it was still largely a developed country perspective. Developing countries often have very different perspectives. First of all, LDCs are struggling to raise literacy rates, lower death rates, increase life expectancy, provide employment for burgeoning populations and reduce local

air and water pollution that pose imminent health hazards to their citizens and environments. Protecting species or slowing climate change are simply low on their priority lists as compared to more mature economic powers like the OECD nations. It is ironic, even if understandable, that LDCs put abatement of global change disturbances so low on their priority lists despite the fact that nearly all impact assessments suggest that it is these very countries that are most vulnerable to climatic change, for example.

There is a phrase in economics known as "the marginal dollar." In our context it means that given all the complexity of interconnected physical, biological and social systems, climate abatement may not be perceived as the best place to invest the next available dollar so as to bring the maximum social benefit to poor countries. I have heard many representatives of LDCs exclaim that until poverty is corrected, preventable disease stamped out, injustice redressed and economic equity achieved, they will invest their precious resources on these priorities. My response has been that climatic changes can exacerbate all of those problems they rightly wish to address, and thus we should seek to make investments that both reduce the risks of climate change and help with economic development (transfer of efficient technologies being a prime example). It is a great mistake, I believe, to get trapped in the false logic of the mythical "marginal dollar," for it is not necessary that every penny of the next available dollar go exclusively to the highest priority problem whereas all the rest (particularly problems with surprise potential and the possibility of irreversible damages) must wait until priority one is fully achieved. To me, the first step is to get that marginal dollar cashed into small change, so that many interlinked priority problems can all be at least partially addressed. Given the large state of uncertainty surrounding both the costs and benefits of many human and natural events, it seems most prudent to address many issues simultaneously and to constantly reassess which investments are working and which problems -- including global change -- are growing more or less serious.

It takes resources to invest, of course, and since the bulk of available capital is in developed countries, it will require international negotiations -- "planetary bargaining" it has been called -- to balance issues of economic parity and social justice with environmental protection. Such negotiations are underway under U.N. auspices, and will likely take many years to work out protocols that weigh the diverse interests and perceptions of the world's nations.

There is a lively debate among economists, technologists and environmentalists about what are the most cost-effective strategies for abating carbon emissions which also can reduce potential impacts of climatic changes to below the undefined "dangerous" levels referred to in the Framework Convention on Climate Change language. Most economists argue that some policy to "internalize the externality" of potential climate damage is already appropriate, reflecting the recommendations already published by the National Research Council in 1991. Environmentalists usually argue that major efforts to spur immediate abatement of carbon emissions are necessary if climatic changes less than one more degree Celsius are to likely be avoided (which they typically define as "dangerous"). Most economists, on the other hand, often argue that new technologies will be able to accomplish carbon abatement more cheaply in the future as such technologies are discovered and deployed (Wigley et al, 1996). Thus, their logic suggests that a cost-effective time profile of abatement would be to postpone most carbon

reductions until later in the 21st century. This seemingly implacable debate will echo in Kyoto chambers, I am sure, in December 1997.

My colleague, the Stanford University economist Lawrence Goulder, and I have used state-of-the-art economic modeling tools to study this debate, and conclude that both the stereotypical environmentalist (who argue to abate now) and economist positions (abate later) are actually not incompatible, but complimentary! We show (please see the Appendix in which our submitted Commentary to *Nature* magazine is reproduced) that although the economist view that future abatement is likely to be cheaper is probably correct, so too is the environmentalist argument that current actions are urgently needed, since such technologies referred to in economic cost-effectiveness studies won't simply invent themselves. In other words, *policy actions to help induce technological changes are needed now* in order to bring about a profile of cost-effective abatement in the decades ahead. We also address the relative economic efficiency of alternative policy instruments: contrasting carbon taxes versus research and development subsides. Although we recognize the political reluctance of many to embrace any new taxes, in truth, most economic analyses show that a fee for the use of the atmosphere (currently a "free sewer") will reduce incentives to pollute, increase incentives to develop and deploy less polluting technologies, and can be more economically efficient than other policies -- particularly if some of the revenues generated by a carbon tax were recycled back into the economy. R&D subsidies can be economically efficient, our conventional economic analyses suggest, to the extent that current R&D markets are already subsidized or otherwise not optimally efficient -- a likelihood.

Therefore, it is my personal view that all parties should recognize that potential damages to a global commons like the Earth's climate are not mere ideological rhetoric, nor are solutions necessarily unaffordable. Moreover, " win-win" solutions in which economic efficiency, cost-effectiveness and environmental protection can happily co-exist are possible -- if only we put aside hardened ideological positions.

V. Personal Observations On The Global Warming Media Debate

A very intense, too-often personal and ad hominem , media debate has attended the global warming problem in the past five years. As a participant in this process, I can attest to the frustration one experiences in seeing a complex scientific problem with many policy implications often trivialized into an ideological boxing match in which polar extremes are pitted against each other and the work of the vast bulk of the knowledgeable community is marginalized. A baffling array of claims and counter claims appears, particularly in op-ed pieces, and a general state of public confusion is fostered. It is my belief that this confusion does not reflect the ordered state of knowledge, in which many aspects of the climate change issue enjoy strong consensual views, other aspects are considered plausible, whereas yet others are clearly (to insiders at least) highly speculative. Public dialogue would be much richer if we all strove to separate out what is well known from what is speculative, an effort not attempted often enough in most public accounts of the issue. How is this best accomplished?

For twenty years the scientific community, or at least the broad cross section scientific community represented by the deliberations of the National Research Council, IPCC and other

international assessment groups, have suggested that if CO_2 were to double and be held fixed, then at equilibrium (i.e. the change in steady state after a few hundred years) the earth's temperature would warm up some one and a half to four and a half degrees centigrade -- the uncertainty, as noted earlier, in this climate sensitivity range largely being associated with the well recognized processes that we treat crudely in our climate models, mostly clouds and water vapor. The reason that very few scientist set the climate sensitivity range above four and a half degrees or below one and a half degrees is primarily because of natural experiments such as ice ages, volcanoes and seasonal cycles, as well as other technical questions dealing with theory and modeling (see IPCC 1996a for details). Nevertheless, a few have asserted, some with very high confidence, that global warming from CO_2 doubling would only cause a few tenths of a degree C equilibrium temperature rise, and even have argued that certain processes that they can name, but cannot demonstrate to have global scale effects, would be responsible for this diminishing effect (e.g. Lindzen, 1990). Such debates (e.g. see Schneider, 1990) are very difficult for the lay public to penetrate, and even for relatively skilled but still non-professional observers, they are hard to follow. It is for such reasons that groups like the National Research Council or The World Meteorological Organization and the United Nations Environment Program have called a community of scientists holding a spectrum of views, but all knowledgeable in the basic art, to meet together to debate the relative merits of various lines of evidence and to provide assessments which give the best guess as well as a judgment for the ranges of uncertainty of a variety of climate changes, as well as their potential impacts on environment and society and the costs of mitigation from alternative policies. Indeed, the Intergovernmental Panel on Climate Change (IPCC 1996a, b, and c) is now the premier such assessment activity and represents the effort of hundreds of directly involved scientists and thousands of indirectly involved scientists, industrialists, NGOs or policy makers who serve as reviewers and commentators.

The IPCC Peer Review Processes Let me contrast the IPCC process with that of some of its critics. In July of 1996 an extraordinary meeting of about six dozen climate scientists from dozens of countries took place. It was the third installment of a process to write a Second Assessment Report for the IPCC. This meeting, in Asheville, North Carolina, was designed to make explicit the points of agreement and difference among the scientists over exceedingly controversial and difficult issues, including the signal detection and attribution chapter -- the most controversial. Chapter 8 was controversial since new lines of evidence had been brought to bear by three modeling groups around the world, each suggesting a much stronger possibility that a climate change signal has been observed and that its pattern (or fingerprint) is much closer matched to anthropogenic caused changes than heretofore believed. Scientists are by nature a skeptical lot, and typically submit their work for peer review before publishing. When scientists have new ideas or new tests, as the dozen or so representing these modeling groups in fact had, they typically write a journal article and submit it for publication. The journals, peer reviewed of course, typically send the article out to two or three peers, who write anonymous reviews, (unless the reviewers have the courage to confess as I, the editor of the journal Climatic Change, encourage my reviewers to do). The authors then rewrite their article in response to the reviewers and the editor serves as referee. The process usually goes back and forth several times

with several revised drafts of the article until a suitable compromise is achieved among reviewers, authors and the editor.

Contrast this normal journal peer review process in which a few people are involved, with what happened in Asheville in 1995 at the IPCC's third workshop. Ben Santer from Lawrence Livermore National Lab, who had assembled the results of a number of modeling groups and was the first author of the submitted manuscript (Santer et al, 1996) on climate signal detection and the Convening Lead Author of Chapter 8 of the IPCC report (the controversial IPCC chapter on signal detection and attribution), presented the results of his group's effort not to just the half dozen Lead Authors of Chapter 8, as is typical in IPCC meetings, but to the entire assembled scientific group at Asheville. Not only did Santer have to explain the work of him and his colleagues (many of whom were there) to his most knowledgeable peers, but also to scores of others from communities as diverse as stratospheric ozone experts like Susan Solomon and Dan Albritton, to satellite meteorologists like John Christy or biospheric dynamics experts such as Jerry Melillo. Climatologists such as Tom Karl or myself were also present, along with heads of weather services and other officials from several countries who served on the IPCC's assessment team as a member of the scientific delegations of the various nations. Not everybody was equally knowledgeable in the technical details of the debate, of course, but even these less familiar participants served an essential role: of witnesses to the process of honest, open debate. Perhaps only twenty-five percent of those assembled had truly in-depth knowledge of the full range of details being discussed. However, all understood the basic scientific issues and most know how to recognize slipshod work -- to say nothing of a fraud or a "scientific cleansing" -- when they see it. This remarkable session lasted for hours, was occasionally intense, always was cordial, and never turned polemical. As a result, words for Chapter 8 were changed, ideas and concepts altered somewhat, but by and large basic conclusions were unchanged because the vast bulk of those assembled (and no one proclaimed to the contrary) were convinced that the carefully hedged statements the lead authors proposed were, in fact, an accurate reflection of the state of the science based upon all available knowledge -- including the new results. This was not only peer review, but this was peer review ten times normal! As the editor of a peer review journal it would be inconceivable for me to duplicate this process, as I have to hope that a few referees and myself can serve the peer reviewing role half as well as this remarkable, open process at Asheville. Moreover, after the Asheville meeting there were two more IPCC drafts written and reviewed by hundreds of additional scientists industrialists, policy makers, and NGOs from all over the globe.

Contrast this open IPCC process then, to the harsh critics of the IPCC, alleging "scientific cleansing", "herd mentality", and first presenting their detailed technical counter arguments in such "refereed scientific literature" as the editorial pages of the Wall Street Journal (Singer 1996, Seitz 1996,). Some had the temerity, although I do not understand how they could do it with a straight face, to allege that Chapter 8 conclusions were all based upon non peer reviewed work, despite the fact that the Asheville process was ten times normal peer review, to say nothing of the hundreds of scientific reviewers of the next draft of the IPCC report that followed. In the wake of all these reviews, textual alterations needed to be made, and these were minor, but were done over the course of time. The last round of changes were made by the Convening Lead, Ben Santer. Some interests subsequently alleged that these minor changes dramatically altered the

report and, with no evidence, asserted they were politically motivated ("scientific cleansing" one charged -- and launched a vicious personal attack on one of the least political, most cautious scientists, Ben Santer). Any honest evaluation will reveal that this irresponsible charge -- published in the unrefereed opinion pages of a business daily -- is utterly absurd. In fact, the most famous line in the IPCC report (that there is a "discernible" human effect on climate) appeared as one sentence in a short paragraph that was 80% caveats! The IPCC report essentially "drips" with caveats.

Moreover, the "discernible" line is not a radical statement, as it reflects a lowest common denominator consensus view of the vast bulk of people exposed to the evidence. It does not assert climate signal detection to be proven beyond any doubt, nor do I or any other responsible scientists I know of make such assertions. Nor can such evidence of human effects be dismissed as wholly random at a very high probability by responsible scientists -- except perhaps in the opinions section of some newspapers. To ignore such contrarian critics would be inappropriate, I agree. However, to give them in news stories comparable weight to a hundred-scientists, thousand-reviewer document, as if somehow a small minority of scientists who are skeptical deserve equal weight, without informing the readership or viewership that the contrarians represent a tiny minority, is to mislead a public who cannot be expected to look up for themselves the relative weights of conflicting opinions. And to publish character-assassinating charges of "scientific cleansing" without checking the facts is simply unethical -- at least in any system of ethics I respect.

VI. Concluding Remarks

A condensed summary of the principal conclusions I would like to draw is as follows, beginning with the more narrowly technical issues and proceeding to broader generalizations about impacts, uncertainties and policy choices:

Hierarchy of models. A hierarchy of models, ranging from simple zero or one-dimensional, highly parameterized models up to coupled three-dimensional models that simulate the dynamics and thermodynamics of connected physical and biological sub-systems of the earth-system are needed for climatic effects assessment. The simpler models are more transparent -- allowing cause-and-effect processes to be more easily traced -- and are much more tractable to construct, run and diagnose, whereas multi-dimensional, dynamical models can provide geographic and temporal resolution needed for regional impact assessments and -- hopefully -- provide more realistic and detailed simulations, even if at much higher costs for construction, computation, diagnosis and interpretability. Since the real climate system is undergoing a transient response to regionally heterogeneous (patchy) forcings (e.g., aerosols and greenhouse gasses combined, which both vary over time and space), eventually it will be necessary to run fully-coupled three-dimensional earth systems models in order to "hand off" their results to a variety of regional impact assessment models. In the interim, lower resolution "simple" climate models can be hybridized into more comprehensive models to produce hybrid estimates of time-evolving regional patterns of climatic changes from a variety of

emissions and land use change scenarios. Such estimates may be instructive to policy makers interested in the differential climatic impacts of various climate forcing scenarios and/or various assumptions about the internal dynamics of both climate and impact models.

Sensitivity studies are essential. It is unlikely that all important uncertainties in either climatic or impact models will be resolved to the satisfaction of the bulk of the scientific community in the near future. However, this does not imply that model results are uninformative. On the contrary, sensitivity analyses in which various policy-driven alternative radiative forcing assumptions are made can offer insights into the potential effectiveness of such policies in terms of their differential climatic effects and impacts. Even though absolute accuracy is not likely to be assured for the foreseeable future, considerable precision concerning the sensitivity of the physical and biological sub-systems of the earth can be studied via carefully planned and executed sensitivity studies across a hierarchy of models.

Validation and testing are required. Although it may be impractical, if not theoretically impossible, to validate the precise future course of climate given the uncertainties that remain in forcings, internal dynamics and unpredictable surprise events, many of the basic features of the coupled physical and biological sub-systems of the earth can already be simulated to a considerable degree. Testing models against each other when driven by the same sets of forcing scenarios, testing the overall simulation skill of models against empirical observations, testing model parameterizations against high resolution process models or data sets, testing models against proxy data of paleoclimatic changes and testing the sensitivity of models to radiative forcings of anthropogenic origin by computing their sensitivity to natural radiative forcings (e.g., season radiative forcing, volcanic dust forcing, orbital element variation forcings etc.) comprise a necessary set of validation-oriented exercises that all modelers should agree to perform. Similarly, impacts models should also be subjected to an analogous set of validation protocols if their insights are to gain a high degree of credibility.

Subjective probability assessment. In addition to standard simulation modeling exercises in which various parameters are specified or varied over an uncertainty range, formal decision-analytic techniques can be used to provide a more consistent set of values for uncertain model parameters or functional relationships. The embedding of subjective probability distributions into climatic models is just beginning (e.g., Titus and Narayanan, 1996), but may become an important element of integrated assessment modeling in future generations of model building (e.g., see the discussion of the hierarchy of integrated assessment models in Schneider, 1997b).

"Rolling reassessment." It is obvious that the projection of climatic effects and related impacts will continue to change as the state-of-the-art in both kinds of models improves over the next few decades. Therefore, the most flexible management possible of a global commons like the Earth's climate seems a virtual necessity, since the potential seriousness of the problem -- or even the perception of that seriousness -- is virtually

certain to change with new discoveries and actual climatic and other environmental or social events. Therefore, a series of assessments of climatic effects, related impacts, and policy options to prevent potentially dangerous impacts will be needed periodically -- perhaps every five years as IPCC has chosen for the repeat period of its major Assessment Reports that treat climatic effects, impacts and policy issues as separable assessments. It seems important that whatever policy instruments are employed (to either mitigate anthropogenic forcings or help reduce damage from projected climatic effects) be flexible enough to respond quickly and cost-effectively to the evolving science that will emerge from this rolling reassessment process.

Consider surprises and irreversibility. Given the many uncertainties that still attend most aspects of the climatic change and impacts debate, priority should be considered for those aspects which could exhibit irreversible damages (e.g., extinction of species whose already-shrinking habitat is further stressed by rapid climatic changes) or for which imaginable "surprises" have been identified (e.g., alterations to oceanic currents from rapid increases in greenhouse gasses). For these reasons, management of climatic risks needs to be considered well in advance of more certain knowledge of climatic effects and impacts.

"Win-win" strategies. Economically efficient, cost-effective and environmentally sustainable policies have been identified and others can be found to help induce the kinds of technological innovations needed to reduce atmospheric emissions in the decades ahead. Some mix of emissions "cap and trade" , carbon taxes with revenue recycling, or technology development incentives can provide "win-win" solutions if all parties to the environment-development debate would lower the intensity of their ideological preconceptions and work together for cost-effective and equitable measures to protect the global commons.

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Table 1: Experts interviewed in the study. Expert numbers used in reporting results are randomized. They do not correspond with either alphabetical order or the order in which the interviews were performed.

James Anderson, Harvard University	Michael MacCracken, US Global Change Research Program
Robert Cess, State University of New York at Stony Brook	Ronald Prinn, Massachusetts Institute of Technology
Robert Dickinson, University of Arizona	Stephen Schneider, Stanford University
Lawrence Gates, Lawrence Livermore National Laboratories	Peter Stone, Massachusetts Institute of Technology
William Holland, National Center for Atmospheric Research	Starley Thompson, National Center for Atmospheric Research
Thomas Karl, National Climatic Data Center	Warren Washington, National Center for Atmospheric Research
Richard Lindzen, Massachusetts Institute of Technology	Tom Wigley, University Center for Atmospheric Research/National Center for Atmospheric Research
Syukuro Manabe, Geophysical Fluid Dynamics Laboratory	Carl Wunsch, Massachusetts Institute of Technology

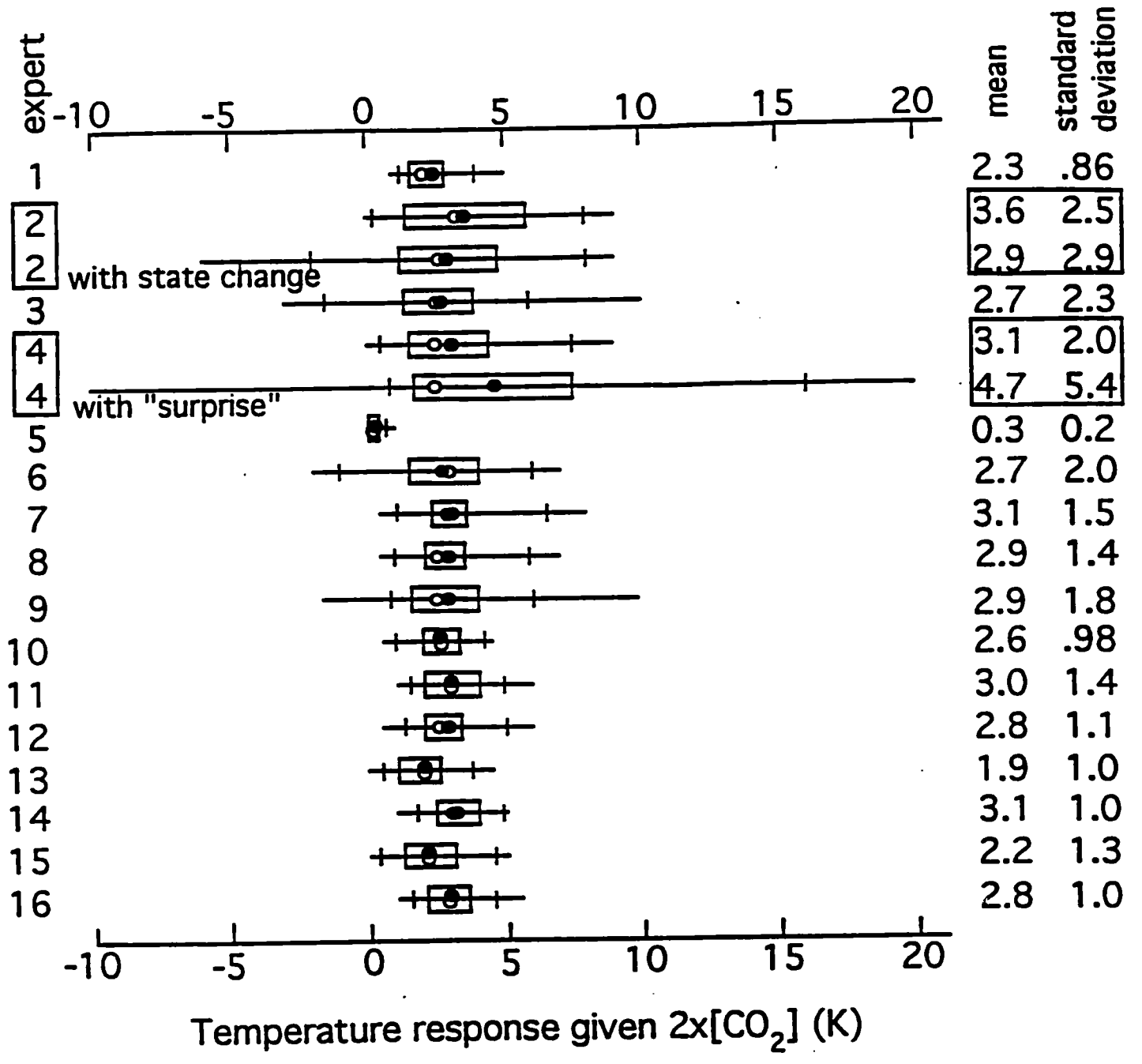

Figure 1 Box plots of elicited probability distributions of climate sensitivity, the change in globally averaged surface temperature for a 2x[CO_2] forcing. Horizontal line denotes range from minimum to maximum assessed possible values. Vertical tick marks indicate locations of lower 5 and upper 95 percentiles. Box indicates interval spanned by 50% confidence interval. Solid dot is the mean and open dot is the median. The two columns of numbers on right hand side of the figure report values of mean and standard deviation of the distributions.

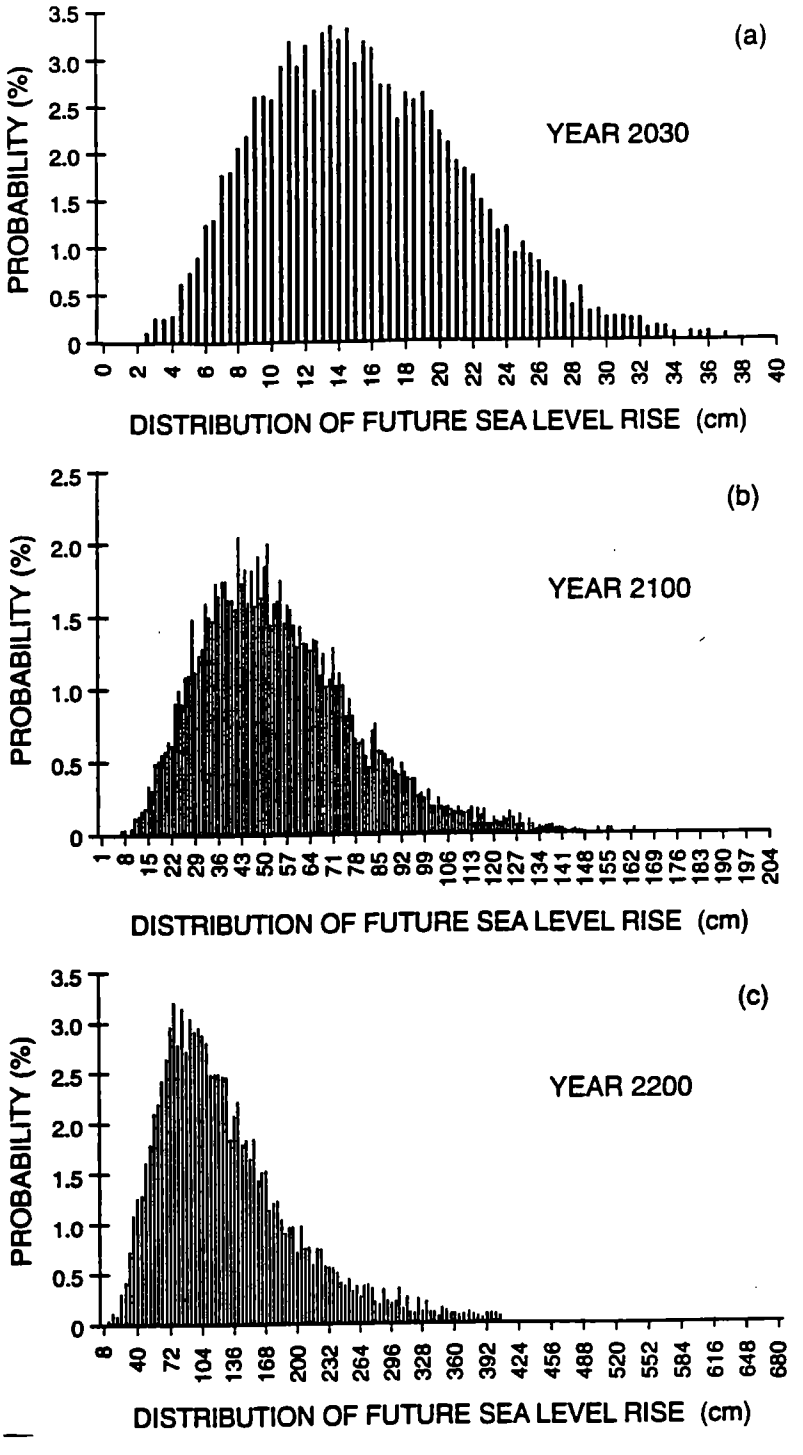

FIGURE 2

Rather than pretend we can know precisely what will happen to climate in the twenty-first century, it is more appropriate to express future scenarios as a probability distribution. Here, James Titus and V. Narayanan have compounded a range of possible CO_2 emission estimates with a range of possible CO_2 concentrations and used the latter to calculate a range of possible climatic changes (sea level rise, in this case). While the probabilities calculated for each specific outcome cannot be taken as quantitatively reliable, the overall shape of the graphs and magnitudes of the changes are representative of state-of-the-art assessments.

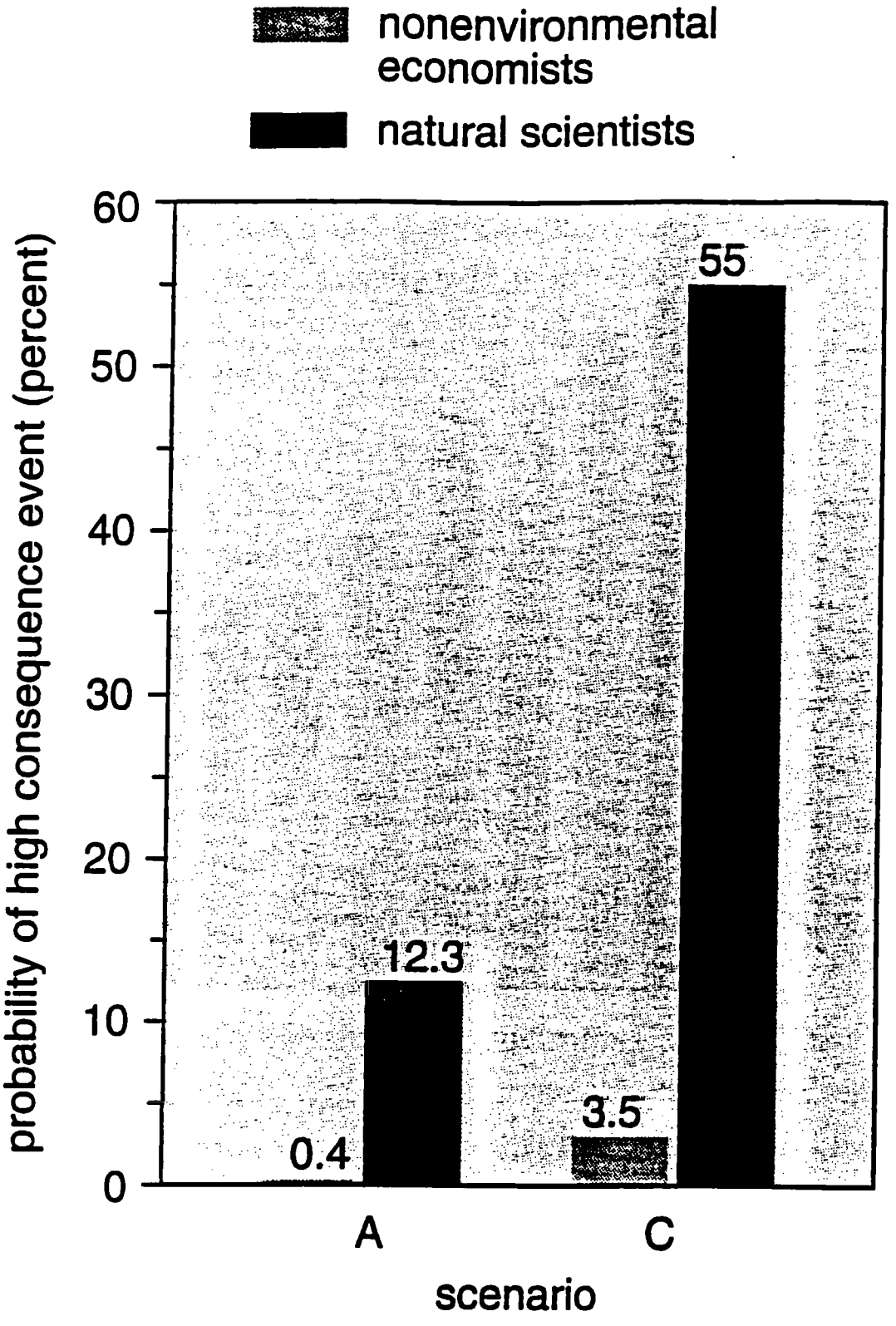

Figure 3. Difference in academic discipline separated those making high estimates of the economic impacts from global warming from those who were comparatively unconcerned. Natural scientists' estimates were 20 to 30 times higher than mainstream economists'. (Nordhaus 1994)

APPENDIX

(Commentary resubmitted to Nature *after initial round of peer review in June 1997)*

Achieving Carbon Dioxide Targets Cost-Effectively: What Needs To Be Done Now?

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I. Introduction

There has been a great deal of discussion about potential ways to reduce the rate of atmospheric accumulation of carbon dioxide (CO_2) and other greenhouse gases. This commentary aims to clarify key economic issues related to the debates about the timing of efforts to reduce CO_2 emissions, and about what policies might be involved in such efforts. We will argue that:

(1) It is crucial to distinguish between the timing of *emissions abatement* and the timing of *abatement policy*. Although there are compelling arguments for relatively small amounts of CO_2 mitigation in the near term relative to the amount of abatement in the distant future, the emphasis on delayed abatement does not justify the absence of policy action in the present or very near future. To the contrary, near-term abatement policy is crucial to bringing about low-cost reductions in CO_2 emissions, even when most of those reductions occur in the distant future.

(2) A carbon tax appears to be the most economically efficient and administratively flexible instrument to employ as part of current policy action.

(3) Under a range of plausible economic assumptions, a carbon tax is a better instrument for generating a cost-effective abatement profile than subsidies to R&D in alternative, low-carbon sources of energy. However, under some circumstances the most cost-effective policy is a combination of carbon tax and an R&D subsidy, where both the tax and subsidy are implemented in the near term.

II. Postponing Abatement Does Not Mean Postponing Policy

This journal recently published a widely cited and instructive article by Wigley, Richels and Edmonds[1] on the appropriate timing of emissions abatement. Wigley *et al.*

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examined several alternative mitigation pathways that culminated in the same long-term concentration of CO_2, and concluded that in general overall abatement costs are kept to a minimum when the bulk of CO_2 abatement takes place in the more distant future rather than in the near term. The article offered four explanations for their conclusion. The first is the positive return on capital: abatement costs in the distant future can be discounted more than nearer term abatement costs. The second is the idea that the capital stock for energy production and end use can be long-lived, which implies that delayed abatement allows orderly replacement of expensive production assets with less carbon or energy intensive new technologies after the older stock has surpassed its economic lifetime. The third is technological progress: over time, new technologies that are less carbon- and energy-intensive are discovered and developed, and this means that the "availability of low-carbon substitutes will probably improve and their costs reduce over time." Wigley *et al.* also use a fourth argument, namely that carbon emitted sooner is exposed longer to natural removal processes than carbon emitted later, and thus delayed abatement permits a larger cumulative emissions total to produce the same long-term concentration target.

The main idea expressed in Wigley *et al.* -- that society can economize on the costs of achieving future concentrations targets by doing more abatement in the future than in the short term -- has won many adherents. However, others (e.g., Ha-Duong, Grubb, and Hourcade[2]) contend that *delaying* current abatement efforts may be costly, since current abatement efforts can be a crucial catalyst for generating the technological progress that ultimately leads to lower costs of abatement.

Much of this disagreement can be overcome if one distinguishes between *emissions abatement* and *abatement policy*. While there are strong arguments to justify concentrating the bulk of emissions abatement in the more distant future, we offer below comparably compelling arguments for implementing, in the near term, government policies that set in motion the sorts of economic adjustments necessary to bring about low-cost reductions in emissions.

III. Introducing a Carbon Tax Today Helps Produce a Cost-Effective Time Profile of Emissions Abatement

Climate-related damages from accumulation of CO_2 represent an "externality" that is not captured in the price of carbon-based fuels.[3] In the absence of government intervention, the market prices of these fuels do not include this important element of social cost. The policy of a carbon tax deals with this problem directly: if set

appropriately, this tax helps market prices better reflect the full social cost. This gives purchasers of fuels the incentive to conserve on use of these fuels and to substitute other inputs. In addition, because the tax will cause prices of carbon-intensive consumer goods to rise relative to the prices of other goods, it gives individual consumers the incentives to alter their purchases and to rely more on less carbon-intensive goods and services, and it gives producers incentives to develop and deploy alternatives.

Of course, other policies could be used to discourage or restrict the use of carbon-intensive fuels. These include direct limits or caps on fuel use, fuel-efficiency standards, and mandated technologies or equipment. An extensive economics literature compares these alternative instruments with the carbon tax.[4,5] This literature tends to embrace the carbon tax as the most economically efficient and flexible instrument, because it economizes on policy makers' information requirements, provides dynamic incentives (discussed below), is relatively inexpensive to administer, and is relatively easy to adjust in response to new information (a virtual certainty in climate-assessment) in comparison with technology mandates. Moreover, a carbon tax would bring in government revenue that could be used to finance cuts in ordinary income taxes, thereby helping avoid the inefficiencies associated with the disincentives to work or to save implied by income taxes. Recent work indicates that this ability to generate revenues makes the carbon tax much more efficient relative to quantity limits on carbon use.[6]

It is important to recognize that an appropriately scaled carbon tax also helps insure the most efficient time-profile for abatement. We concur with Wigley *et al.*'s argument that cost-effectiveness requires that the bulk of carbon emissions abatement (relative to the path of emissions under an unconstrained business-as-usual scenario) occur in the future rather than the present. *But concentrating abatement in the future does not justify avoiding carbon taxes in the near term.* Economic analysis indicates that carbon tax rates should be set according to the "marginal environmental damage" from CO_2 emissions. Most analyses indicate that this implies a carbon tax of rising rates through time[3,7,8]. Rising tax rates help encourage ever-increasing amounts of abatement. Moreover, even a *constant* carbon tax rate, though less than optimal from the point of view of economic efficiency, is consistent with a rising time-profile for abatement. This reflects the idea that, as new technological options for emissions- (or fuel-) abatement are discovered and implemented, the profit-maximizing amount of emissions abatement expands -- even if the tax rate is constant. Thus, there is no contradiction between the

current introduction of carbon taxes and the cost-effective time profile for emissions abatement.

Moreover, introducing the carbon tax in the near term is a key ingredient to speeding up the technological change that justifies more future abatement relative to near-term abatement. By making the use of carbon-based fuels more expensive, a carbon tax provides incentives to engage in R&D aimed at the discovery and development of alternative energy supply and energy end-use options. While the *rationale* for a carbon tax is the need to incorporate into the price of carbon-based fuels the externalities associated with carbon use, an important bi-product of this tax is the stimulation of R&D and (presumably) technological progress in alternative energy sources. As emphasized by Ha-Duong, Grubb, and Hourcade, a carbon tax can also stimulate technological change by promoting "learning-by-doing." In the climate-change context, this means that experience with processes that reduce CO_2 emissions can generate new knowledge as to how to reduce emissions more cheaply. In our view, the carbon tax is a useful vehicle for exploiting this phenomenon. By introducing the tax (now), one promotes greater experience with alternatives to conventional fuels, which in turn sparks technological innovation.

IV. R&D Subsidies vs. Carbon Taxes

Does the carbon tax's ability to stimulate R&D mean there is no justification for introducing an R&D subsidy as part of climate-change policy? A general economic principle is that governments should apply the policy instrument most closely related to the particular "market failure" at hand. As noted, the central market failure here is the climate-damage externality associated primarily with combustion of carbon-based fuels, and that the carbon tax is the policy instrument that is directly oriented to that failure. A subsidy to R&D does not directly deal with this market failure, because it does not directly alter the prices of carbon-based fuels. If there were no other market failures to be concerned about, an R&D subsidy would be unnecessary: the carbon tax alone would be up to the task of reducing in a cost-effective manner the accumulation of CO_2.

However, there is a *second* market failure to consider in connection with climate policy -- failure in the market for R&D. It is well known that private investments in research and development may generate "spillover benefits" that are enjoyed by parties other than the party making the investment. (For example, when an electronics firm invests in R&D in new production methods, the fruits of that investment may be enjoyed

in part by other firms.) Not all knowledge can be kept as private knowledge. Economic theory indicates that, under these circumstances, firms tend to under invest in R&D, mainly because they do not take into account the full social value (including the spillover benefits) when they make the investments. A government subsidy to R&D can correct this market failure. The ideal subsidy would lower the firm's cost of R&D enough to cause the firm to expand its investment in R&D to the socially optimal level.

Does this theoretical argument imply that a carbon tax should be accompanied by an R&D subsidy to alternative, low-carbon or carbon-free energy supplies? It depends. The theory suggests that an R&D subsidy is appropriate wherever there are significant spillovers. If such spillovers arise in connection with virtually all industrial investments in R&D, then the most economically efficient policy response is not a specific R&D subsidy to investments in alternative energy, but rather a broad-based subsidy applicable to R&D investments by a wide spectrum of industries. On the other hand, if such spillovers are particularly significant for investments in alternative energy supplies, then there is a basis for a more specific R&D subsidy, that is, a subsidy targeted to investments in R&D in alternative energy. The resolution of this issue requires further empirical investigation; the evidence to support a targeted subsidy, so far, is scanty. Public policy needs to proceed cautiously here: while there are strong theoretical and empirical reasons to support a carbon tax, the efficiency case for a targeted R&D subsidy is less clear.

[Table 1 about here]

Results from our economic simulation model for the U.S.[9] are in accord with the theoretical ideas just mentioned. (To our knowledge, ours is the only large-scale general equilibrium economic model that treats incentives to invest in R&D, knowledge-spillovers, and the functioning of R&D markets; hence it is uniquely suited to investigate these issues.) The particular numbers are illustrative, and we emphasize the qualitative insights from the results, not the specific numbers. Table 1 shows the costs of reducing cumulative CO_2 emissions by 15 percent over the 100-year period beginning 1995 (the initial simulation year). Panel A of this table evaluates these costs when the model includes no spillovers from R&D investments. In this situation, the cheapest way to attain the target is through a carbon tax alone. In the second panel, we evaluate these costs under the assumption that there are significant spillovers from investments in R&D

by the "alternative energy" industry (that is, the non-carbon-based fuel industry). In this case, the combination of carbon tax and R&D subsidy to alternative energy represents the most cost-effective way to attain the abatement target. This combination is cheaper that the combination of carbon tax and *broad* subsidy to all investments in R&D. Panel C considers the case where *all* investments in R&D involve significant spillovers. In this case, the least-cost policy involves a combination of carbon tax and *broad* subsidy to R&D. In no case does the R&D subsidy by itself offer the cheapest way to meet the target reduction in cumulative emissions; indeed, when the R&D subsidy is introduced alone, the costs of meeting the target are several times higher than in the other cases. These results support the idea that a carbon tax is essential for cost-effective reductions of CO_2 emissions, and that this tax should be accompanied by an R&D subsidy only to the extent that there are spillover benefits from R&D.

A caveat is in order. If R&D markets are already highly inefficient (e.g., distorted by prior subsidies or taxes), then gauging the costs of *new* R&D subsidies applied to low-carbon sources of energy becomes more complicated. Depending on the array of pre-existing subsidies, the costs of a combination of carbon tax and R&D subsidy might be higher or lower than what is suggested in Table 1. These qualifications do not contradict the general principle that to maximize economic efficiency R&D subsidies are warranted only insofar as there are spillovers in R&D markets.

V. Two Further Considerations

Political Considerations

We have emphasized that a carbon tax is a crucial instrument for producing a cost-effective abatement path. However, this policy is likely to be less popular than subsidies to R&D in new energy technologies. Producers tend to abhor taxes and embrace subsidies, for obvious reasons. But a policy consisting only of R&D subsidies would not likely reduce emissions in the lowest-cost manner. It is also worth noting that while an R&D subsidy is more favorable to producers, a carbon tax is more attractive to general taxpayers (although some low income groups express concern about its potential regressivity). An R&D subsidy needs to be financed through other tax revenues; in contrast, under a carbon tax policy the government can "recycle" carbon tax revenues, that is, use the revenues to finance cuts in individual income taxes, to the benefit of

general taxpayers (including lower income groups). Balanced discussions of policy options require attention to these impacts on the tax-paying public.

We have concentrated our analyses on issues of cost-effectiveness and economic efficiency. Of course, in the political arena there are advocates for other policy principles, such as the precautionary principle or the principle of stewardship. Our purpose here is not to debate the relative merits of alternative criteria for policy choices, but simply show that a "do-nothing" policy is difficult to justify, even according to a policy criterion endorsed by most economists.

Uncertainty

Thus far we have ignored a key issue related to the policy problem: uncertainty. We cannot address this issue in detail here. Some claim that current policy action is premature, given the uncertainties about the likely extent of climate change and the associated damages. Others maintain that the postponement of policy action could necessitate more substantial, and much more costly, future action if such action were ultimately required. Analytical work on this issue indicates that current policy action remains worthwhile, despite the uncertainties, provided that there are not prohibitively high "sunk costs" of introducing the policy in question[10,11] . An attraction of a carbon tax policy is that it involves very minimal sunk costs, which suggests that near-term action is warranted. Moreover, it is flexible enough to allow adjustments as new information as to of the seriousness of climate change and the effectiveness of policy tools becomes available.[12]

VI. Conclusions

It may be cost-effective to parcel most of the *abatement* of CO_2 in the longer term rather than the near term. But we emphasize that current *policy action* is needed to bring about a cost-effective time profile of abatement, even if most abatement takes place in the future. We would argue that a carbon tax (or some other flexible policy that directly confronts the evolving climate-change externality from fossil-fuel combustion) is an essential element of greenhouse policy. An R&D subsidy may be justified as complement to a carbon tax when there are R&D market failures. But the case for the subsidy (in terms of economic efficiency) rests primarily on spillover benefits from R&D rather than on the prospect of environmental damages from the atmospheric buildup of CO_2.

Table 1

Costs of Achieving 15 Percent Reduction in Cumulative CO_2 Emissions Over Period 1995-2095

(Percentage Reduction in Present Value of GDP)

Scenario	Carbon Tax Alone	Targeted R&D Subsidy Alone	Carbon Tax Plus Targeted R&D Subsidy		Carbon Tax Plus Broad R&D Subsidy	
			subsidy rate = 1%	subsidy rate = 5%	subsidy rate = 1%	subsidy rate = 5%
A. No Spillovers from R&D	.416	1.355	.427	.444	.483	.523
B. Spillovers from R&D by Alternative Energy Industry (only)	.382	1.294	.366	.350	.380	.412
C. Spillovers from R&D Investment by All Industries	.433	1.323	.441	.455	.401	.319

Note: All simulations involve carbon tax rates that increase at a rate of 5 percent annually through the year 2075 and remain constant thereafter. In each scenario, the carbon tax profile is the lowest path of (rising) tax rates that leads to the desired reduction in cumulative emissions.

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Statement for SEJ "Naysayers versus Doomsayers" Debate, St. Louis, MO
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Ten minutes of presentation time does not remotely permit me an opportunity to discuss the volumes of scientific information that bolster the concerns expressed by thousands of scientists about the likelihood and seriousness of global environmental changes. While acknowledging at length that many uncertainties remain, the 1995 Intergovernmental Panel on Climate Change (IPCC 1996) stated, "nevertheless, the balance of evidence suggests that there is a discernible human influence on climate." This well traveled statement is not, by analogy, intended as the "beyond a reasonable doubt" criterion of criminal trials, but rather is more in the "preponderance of evidence" spirit of civil cases.

The kinds of evidence (much of it circumstantial, but growing) assessed by IPCC authors include:

(1) A well validated physical theory (i.e. natural "greenhouse effect")
(2) Well documented human-induced increases in CO_2, CH_4, SO_2. etc.
(3) Paleoclimatic evidence of links between temperature and CO_2/CH_4.
(4) Paleoclimatic and historic evidence showing 0.5°C 20th century warming trend to be unusual (probably unprecedented in the past 600 years)
(5) Twenty-five years of validation and testing of climate models have not substantially altered most estimates of global surface temperature change ranges (i.e. 1.5 to 4.5°C for 2 x CO_2). Such tests include seasonal cycle of surface temperature, response to volcanic eruptions and many paleoclimatic model/data comparisons.
(6) Recent comparisons of "fingerprints" of climatic changes from CO_2 and SO_2 driven models give better match with observations than CO_2-only driven models.
(7) Human activities (i.e."business as usual") likely to lead to large increases in CO_2, etc.

Rather than try to squeeze anymore science into my remaining few minutes, let me, instead talk about process: the process of scientific and environmental assessment, that is.

I began my scientific career as a skeptic -- calculating in 1971 that global increases in aerosols could dominate greenhouse gases and lead to planetary cooling. I then extended the skepticism to myself, showing in the refereed literature (Schneider, 1975) and popular books (Schneider, 1976) why I was probably wrong at first (because aerosols are largely regional, not global and the stratospheric greenhouse effect cannot be neglected). That is what scientists grappling with complex problems must do -- correct their projections when new data or ideas become available to them.

Thus despite the apparent label imputed to me from the title of this debate (that I'm a "doomsayer"), I'm actually a "naysayer". More examples: in 1976 I co-authored the first paper (with R. Chervin) that defined how to test the statistical significance of complex computer model experiments so false claims of cause and effect could be rejected; in 1981 Starley Thompson and I published the first study showing that so-called "equilibrium CO2-doubling" experiments in climate models probably would not produce a realistic pattern (i.e. "fingerprint") of climate change and again in 1994 (in Science) I reinforced that theme and added to it the need to include geographically patchy forcing factors like sulfate aerosols (tying

it back to my 1971 work on global aerosol cooling); and my most noted "naysaying" was to stand up to an entire movement in 1984-6 that had been using "nuclear winter" as the motivation for dramatic nuclear arms reduction as Thompson and I showed that scientifically (not politically, since I agreed on other grounds with the need for arms control) the most likely scenario was a milder "nuclear autumn" -- for which I was attacked by "peace" groups and celebrated by many of the same interests that today label me as "extreme" or "doomsaying" in the global environmental change debate. What I was doing then -- and now-- was -- and is -- science -- letting the evidence accumulate and building my views as to the likelihood of a range of outcomes (from beneficial to catastrophic) based on how the community of scholars uncovers and debates the evidence.

So I am a well documented "naysayer". But I'm also a "doomsayer", as the debate organizers have predicted, because I believe that so much uncertainty still accompanies problems like global warming and species extinction that I foresee a significant chance (i.e., greater than ten percent probability) for catastrophic outcomes (like a major extinction crisis or serious disease outbreaks being exacerbated by the synergism of habitat fragmentation, introduction of non-native "exotic" species and anthropogenic climate changes). In my value system we should consciously focus on such negative outcomes, not because all imaginable pessimistic possibilities are necessarily our most likely future, but because problems are what we want to avoid. Are we all "doomsayers" for buying health or house insurance, for hedging our bets by making conservative business investments or for advocating personal or national security expenditures despite the low probability that we personally will be attacked? In this risk-averse context I'll wear the "doomsayer" label proudly. What I like least is polarized labeling. It sometimes makes a convenient storyline, but it rarely captures the breadth of most scientists' views on complex problems.

The key scientific and policy problems are (1) how to assign (essentially subjective) probabilities to the range of foreseeable outcomes from beneficial to catastrophic, and (2) whose estimates should be trusted. My answer is "nobody's" -- that is, no individual's. Scientific assessment of global environmental change is (1) multidisciplinary -- it needs physical, biological and social scientists as well as decisionmaking groups -- and (2) complex systems are not perfectly understood. These two factors suggest, no require, that broadbased communities of scholars and decisionmakers be part of the assessment process. No one of us has enough wisdom to cover all the intellectual bases, even if we need to represent in some forums many aspects of the community knowledge we learned through the assessment process. In the climate change case, community assessment was most frequently undertaken by committees of the US National Academy of Sciences, and more recently (past seven years) by the IPCC. Despite shifts of emphasis or details from report to report, the basic conclusions of these broad based assessments have been remarkably unchanged for two decades: both mild and catastrophic (i.e. less than 1°C or more than 5°C warming in the next century) outcomes are possible but improbable (i.e. typically less than ten percent subjective likelihood). These subjective probabilities from mainstream science are also very close to my own (see Fig. 1 of Morgan and Keith, 1995 -- I am scientist #9).

Contrast our conservative estimates that consider "the end of the world" or "nothing at all" as low probability outcomes with the subjective probabilities of "naysayers" like MIT's Richard Lindzen (scientist #5 on Fig. 1 of Morgan and Keith, 1995). He, and other such self-confessed "contrarians" not only assign a very high probability to negligible outcomes, but either don't discuss or disdain the possibility that the more serious outcomes that the bulk of the scientific community believes to be most probable could even occur. And for this narrow view they are often cited to "balance" media stories that

pit one or two of a half a dozen such "naysayer" scientists versus spokespersons for a thousand mainstream scientists who openly admit that negligible outcomes are possible, just unlikely given what we now know. I'm not suggesting that extreme views should be ignored, only reported in the context of mainstream opinions since most readers/listeners can't easily know that two opposing opinions do not carry the same scientific weight.

Similarly, "naysayers" have asserted that even if climate change occurs as projected it is likely to do no economic or environmental harm and that those who assert otherwise are just "doomsaying". Yale economist, William Nordhaus, hardly known as a "doomsayer", surveyed the opinions of mainstream economists, environmental economists and natural scientists finding that the former, indeed, had a factor of twenty less anxiety about the economic or environmental consequences of climate change than the later. However, the bulk of even the conservative group of economists considered there to be at least a ten percent probability that typically projected climate changes could still cause economic damages worth several percent of gross national product (the current US GNP is around five trillion dollars -- about twenty percent of the global figure). And, some of these economists didn't figure in costs of "non-market" damages (i.e. harm to nature). One ecologist who did even went so far as to assign a ten percent chance of a hundred percent loss of GNP -- the virtual end of civilization! While Nordhaus asserted that those who know most about the economy are less concerned I, (I am respondent #10, in Nordhaus, 1994) countered with the obvious observation that those who know the most about nature are very concerned.

We will not easily resolve the paradigm gulf between the optimistic and pessimistic views of these specialists with different trainings, traditions and world views, but the one thing that is clear from both the Morgan and Keith and Nordhaus studies is that the vast bulk of knowledgeable experts from a variety of fields admit to a wide range of plausible outcomes in the area of global environmental change -- including mild and catastrophic eventualities under their broad umbrella of possibilities. This is a condition ripe for polemics by those who abuse the openness of the community (which admits the possibility of opposite extreme outcomes). Such polemicists then take extreme or mild outcomes and inflate them as if they were our most likely future, and next fax this special interest distortion in press releases from one end of the world to the other.

Citizens, decisionmakers and journalists alike should beware of those who profess great confidence in their brand of highly certain "truth". Myth busters, truth tellers and the cocksure all share one characteristic: inflated certainty about global climate change issues. Once in a while a Copernicus comes along to overthrow some wrongheaded scientific dogma. But I'll bet that for every real Copernicus there are thousands of pretenders. For science, consensus is certainly not equivalent to truth. There are many remaining measurements to make and theories to test. But for policymaking, consensus assessments from the NAS or IPCC are the best guides we have. An IPCC report may be cumbersome, and hard to characterize in a polarized storyline, but it comes way closer to the best available science than the elliptical pronouncements of a handful of contrarian scientists whose extreme views are amplified way beyond their credibility by special interest megaphones and then faxed to journalists and policy makers across the planet. The signal to noise ratio of the climate debate may be more baffling to the public than the problem of detecting a human-induced climate signal out of the noise inherent in natural climatic variability is to the scientist. There are not likely to be highly certain conclusions anytime soon. Meanwhile, habitats continue to be fragmented and pollutant emissions continue to grow, exacerbating the "great geophysical experiment" we are performing on Laboratory Earth.

For those interested in more depth on my personal views about the science and assessment issues, they are most recently expressed in my forthcoming book *Laboratory Earth: The Planetary Gamble We Can't Afford to Lose*, (UK edition published October 1996 by Weidenfeld & Nicolson, London and the US edition to be published January 1997 by Harper Collins, Basic Books, New York).

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CLIMATE CHANGE

Subjective Judgments by Climate Experts

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Structured interviews using "expert elicitation" methods drawn from decision analysis were conducted with 16 leading U.S. climate scientists. We obtained quantitative, probabilistic judgments about a number of key climate variables and about the nature of the climate system. We also obtained judgments about the relative contributions of various factors to the uncertainty in climate sensitivity. We found strong support for the importance of convection/water vapor feedback and of cloud optical properties. A variety of questions were posed to elicit judgments about future research needs and the possible sources and magnitude of future surprises. The results reveal a rich diversity of expert opinion and, aside from climate sensitivity, a greater degree of disagreement than is often conveyed in scientific consensus documents. Research can make valuable contributions, but we interpret our results to mean that overall uncertainty about the geophysics of climate change is not likely to be reduced dramatically in the next few decades.

When scientific uncertainty limits analytic modeling, but decision makers cannot wait for better science, expert judgment can be used in the interim to inform policy analysis and choice. Approaches such as the "Delphi method" (*1, 2*) have been developed to obtain consensus summaries. Without using formal methods, scientific panels, such as those of the Intergovernmental Panel on Climate Change (IPCC) (*3*) or the National Research Council (NRC) (*4*) often strive to produce consensus summaries.

However, when uncertainty is high because of fundamentally different views about underlying physical processes, a consensus summary may not best serve policy analysis needs. An alternative approach, widely used in applied Bayesian decision analysis (*5–7*), formalizes and quantifies the judgment of individual experts through expert elicitation (*8–11*). Subsequent analysis of results allows conclusions about the importance of the range of expert opinions to the overall policy debate. Apparent deep disagreements can make little difference to the policy conclusions or be critically important (*11*).

We conducted detailed expert elicitations with 16 leading climate scientists as part of a Carnegie Mellon program of integrated assessment of climate change (*12*). Several limited elicitations on climate-related topics have been reported in the literature [*13* (for a critique see Stewart, T. R.; Glantz, M. H. *Climate Change* 1985, *7*, 159–83), *14*, *15*], but ours were more technically detailed. Because we were concerned about both model uncertainty and parameter uncertainty, we also developed several new question designs and response modes not used in previous elicitations.

The results reveal a rich diversity of expert opinion. Aside from estimates of climate sensitivity, defined here as the global average surface warming caused by a doubling of carbon dioxide concentrations, they indicate a greater disagreement than we believe is usually conveyed in scientific consensus documents. We are aware of one instance in which such a panel attempted to use subjective probability distributions to characterize uncertainties (*16, 17*). Although such techniques require time and care, we believe that more general use of these methods could improve communication significantly.

We find there is almost no agreement about the effect of climate change on policy-relevant factors such as changes in precipitation over land and various forms of interannual variability. However, experts agree that uncertainties in policy-relevant measures, such as climate sensitivity, could be reduced by about 20% over the next decade or two if research substantially improves understanding of convection/water vapor feedback or cloud optical properties. Research on oceanic convection and CO_2

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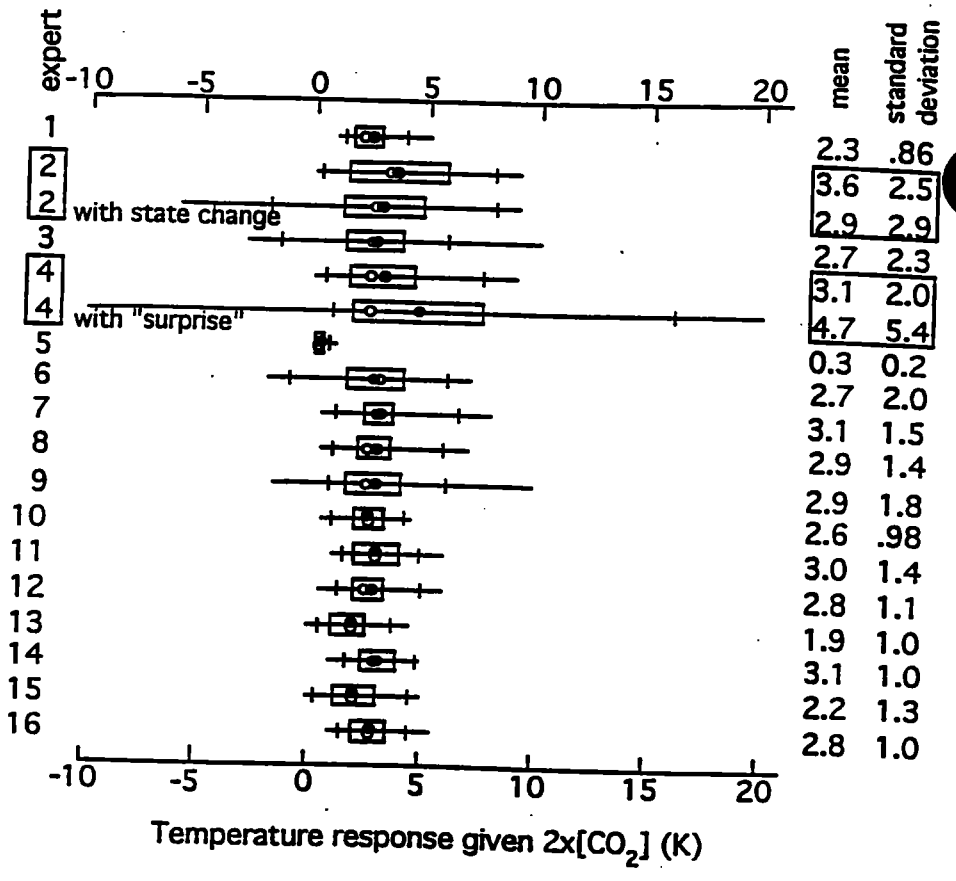

Figure 1 Box plots of elicited probability distributions of climate sensitivity, the change in globally averaged surface temperature for a 2x[CO_2] forcing. Horizontal line denotes range from minimum to maximum assessed possible values. Vertical tick marks indicate locations of lower 5 and upper 95 percentiles. Box indicates interval spanned by 50% confidence interval. Solid dot is the mean and open dot is the median. The two columns of numbers on right hand side of the figure report values of mean and standard deviation of the distributions.

Table 1: Experts interviewed in the study. Expert numbers used in reporting results are randomized. They do not correspond with either alphabetical order or the order in which the interviews were performed.

James Anderson, Harvard University	Michael MacCracken, US Global Change Research Program
Robert Cess, State University of New York at Stony Brook	Ronald Prinn, Massachusetts Institute of Technology
Robert Dickinson, University of Arizona	Stephen Schneider, Stanford University
Lawrence Gates, Lawrence Livermore National Laboratories	Peter Stone, Massachusetts Institute of Technology
William Holland, National Center for Atmospheric Research	Stanley Thompson, National Center for Atmospheric Research
Thomas Karl, National Climatic Data Center	Warren Washington, National Center for Atmospheric Research
Richard Lindzen, Massachusetts Institute of Technology	Tom Wigley, University Center for Atmospheric Research/National Center for Atmospheric Research
Syukuro Manabe, Geophysical Fluid Dynamics Laboratory	Carl Wunsch, Massachusetts Institute of Technology

Expert Opinion on Climatic Change

Interviews with social and natural scientists reveal vast disparities in estimates of the economic impact of potential greenhouse warming

William D. Nordhaus

Concerns about the prospect of global warming offer a signal example of the tension between two different views of the relation between economic growth and resources.

At one extreme lies a cheerful frontier mentality that looks forward to limitless economic expansion for the human race. The earth, in this view, has endless rangeland to graze, oceans of offshore oil and gas for drilling, deserts on which to build airports and parking lots, and substitutes readily available wherever scarcities arise. The frontier view sees human societies adapting readily to the modest projected rise in global temperatures that might accompany greenhouse warming. "Frontierniks" might anticipate a new frontier in Russia and other polar regions, trusting that warming will open vast new terrain for mineral exploitation and human expansion, and perhaps even imagine surfing in Alaska or sunbathing in Siberia.

At the other extreme is a dour conviction that finds constraints on every front for people and especially for the natural systems on which they depend. Economic development will inevitably be limited by the depletion of resources, overpopulation and lethal pollution. In this view, unintended consequences threaten to overwhelm human ingenuity, and we must be ever vigilant lest the dikes that hold back catastrophe break and we find ourselves inundated by the threatening seas. "Limitniks" see clouds behind every silver lining, believe that global warming poses dire risks to natural ecosystems, and hold that these risks will spill over to threaten human civilizations as well. They warn of losses in systems that cannot adapt quickly, such as coral reefs and forests; they worry about invasions of pests and viruses that will be bred in enlarged tropical regions; and they fret about a breakdown in vital human-support systems as we undertake this vast geophysical experiment.

At this point, no one can say with any assurance which of these views of the impact of global warming is the right one or in what measure either is closer to the truth. Neither natural nor social science is capable today of predicting with high confidence how climate may change, nor are the geophysical, ecological or social reactions to such changes easily foreseen.

We have only "best guess" scenarios for climatic change and the social reactions it might cause. And even there, the range of possible alternative outcomes overwhelms even the most fertile imagination. For example, many who analyze the perils of future climatic change argue that the greatest impact would not come from the smooth and linear projection that comes out of climatic and economic models. Rather, the major danger to the human prospect may lie in the low-probability, high-consequence events—possibly including catastrophic changes that are difficult or impossible to foresee.

Because of the difficulties of using conventional techniques to gather information, the present study takes another approach—that of surveying expert opinion. The original purpose of the survey reported here was to establish estimates of impacts of climatic change that could be used in quantitative modeling of global change. Once under way, however, the survey took on a life of its own. It became a means of exploring the diversity of views held by those who have thought deeply about global warming and its impacts and about the extent of uncertainties.

The survey revealed that the range of estimated impacts was indeed enormous, and the stakes in both better understanding and wise policies are clearly equally large. Aside from the not-surprising finding of great dissension, the opinions of experts revealed major differences among disciplines, particularly between mainstream economists and natural scientists. One might even say that over the two centuries since Malthus, economists have cast off the mantle of the dismal science while Malthus's intellectual progeny in ecology and the evolutionary sciences have donned that cloak. But I get ahead of the results, so let us turn next to the survey itself.

How the Survey Developed

I developed the survey in an interactive process with respondents. It started with a letter circulated to three people (two experts in climatic change and one economist who had extensive experience in surveys), outlining the idea. Our discussions led to a letter to several potential respondents inviting them to participate.

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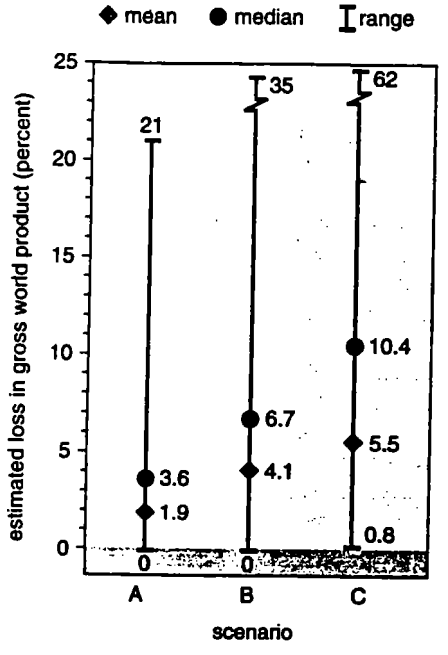

Figure 2. Estimates of the impact on global output in the event of global warming varied greatly among the 19 respondents to the survey. In scenario A, a 3-degree-Celsius rise in global average temperature by 2090, experts predicted a loss ranging from 0 to 21 percent of gross world product (GWP). Ranges for scenario B, a continuation of scenario A to a 6-degree warming by 2175, and scenario C, a more rapid warming of 6 degrees by 2090, were even greater, at 0 to 35 percent and 0.8 to 62 percent of GWP.

volved estimating the impact of climatic change on countries or regions with different levels of income and development. More precisely, respondents were asked to estimate the ratio of the impact on the top quintile to the impact on the bottom quintile of the world income distribution. All but one of the respondents were of the opinion that the developing countries (that is, the lowest quintile) would be more seriously affected than the high-income countries.

The Influence of Point of View

I shall turn next to a qualitative review of the results. The major impression that emerges from this survey is that experts hold vastly different views about the potential economic impact of climatic change. At one extreme are the natural scientists, all three of whom have profound concerns about the economic impacts of greenhouse warming. For example, the mean of these three respondents' answers has a 12-percent probability of severe economic consequences under scenario A. At the other extreme are the "other subdisciplines" of economics (those whose principal concerns lie outside environmental economics); these eight respondents see much less potential for the calamitous outcome—0.4 percent, or about one-30th of the magnitude estimated by the natural scientists. For the more rapid warming in scenario C, the estimated range of probabilities of economic calamity was 20 to 95 percent for the natural scientists and 0.3 to 9 percent for the mainstream economists. The same gap—although it was sometimes less pronounced—ran through the responses to most of the rest of the questions.

What might lead to such a difference in outlook? One respondent suggested whimsically that it was hardly surprising, given that the economists know little about the intricate web of natural ecosystems, whereas scientists know equally little about the incredible adaptability of human economies. One respondent (4) explained the difference of views as follows:

> I have not heard a compelling scenario about the crisis scenario. People tend to have an apocalyptic streak—for example, many scientists held that the probability of nuclear war was a few percent per year in the 1950s and 1960s whereas a more realistic number would have been an order of magnitude smaller. On the basis of that tendency and the ability to adapt, even if climate change were very rapid, it wouldn't be all that terrible....

Another respondent (9) spoke of the views of different participants in the policy debates:

> What is my impression of the view of people involved in the policy process? On the whole, their views are very sketchy and ill-thought-out. People have fears about the future that are not grounded in reality. Scientists tend to be more conservative and don't see such adverse outcomes whereas politicians tend to see weird possible outcomes. There are big differences among people because of the impact of affluence. Policies tend to get discussed in Colorado in August above 7,000 feet, and above 7,000 feet people lose the concept of discount rates.

Apocalypse or Small Potatoes?

The second impression that arises from this survey is that for most respondents the best guess of the impact of a 3-degree-warming by 2090, in the words of respondent 17, would be "small potatoes." Only three respondents expect the impact of scenario A to be more than 3 percent of

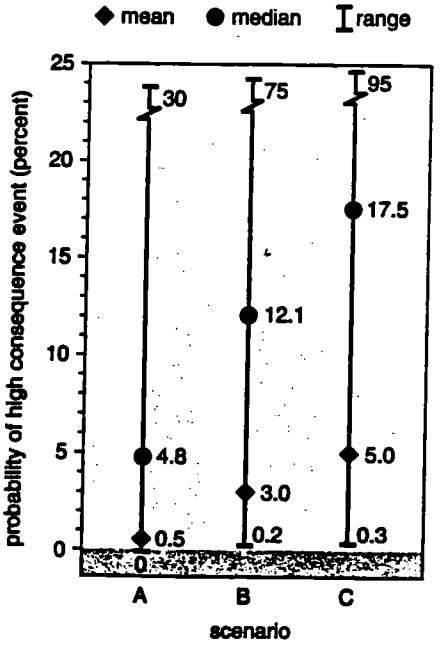

Figure 3. Estimates of the likelihood of a high-consequence event (a loss of at least 25 percent in global output, equivalent to the Great Depression) from global warming give an indication of the potential for catastrophic impacts. Note that averages were greatly affected by a few extreme responses. Estimates went as high as 30, 75 and 95 percent for scenarios A (3-degree warming by 2090), B (continuation of A to 6-degree warming by 2175) and C (6-degree warming by 2075).

GWP. In terms of economic growth, the median estimated impact for scenario A over the next century would reduce the growth of per capita incomes from, say, 1.50 percent per year to 1.485 percent per year. One respondent summarized the relaxed view: "I am impressed with the view that it takes a very sharp pencil to see the difference between the world with and without climate change or with and without mitigation."

Among the problems that face humanity (as opposed to natural systems), global warming does not rank very high for many respondents. Respondent 16 stated that "global warming is way down the list of people's concerns, especially compared to the conventional economic concerns."

Concerns about Ecosystems

Many of the non-economists voiced deep concern about the ability of natural ecosystems to adapt to climatic change, particularly for the large temperature increases. A scientist (respondent 19) stated:

> In [scenario B], I continue to assume that there will be larger temperature

changes in the polar regions of the order of 20 degrees Fahrenheit. In this case, there would be a major change in that we would be moving to a nearly ice-free world with all that would imply. It is hard to imagine what the world would be like with an ice-free Arctic, with a weakening of the circumpolar vortex and a movement of storms to the north, mild temperature in the Arctic regions, agricultural possibilities in high northern latitudes, as well as substantial mid-latitude desiccation....

If we move to the rapid-change case [scenario C], this would add a rapidity of change so that ecosystems could not adjust. The biosphere would be radically changed, and I suspect that there would be severe economic effects.

Secondary Effects

Some respondents foresee the potential for society to respond in highly nonproductive ways as global warming turns from prediction to reality. Respondent 18 stated that as the reality of greenhouse warming becomes clearer, even a modest climatic change "will create a sense of crisis that could lead to short-term irrational policies." A scientist (respondent 10) stated his concerns as follows:

> My concern about future climatic change is a complicated *Gestalt*. I believe that the climatic stresses will make it more difficult to accomplish a number of important objectives, particularly the appreciation or utility of the diversity of nature. Particularly at high rates and numbers, the tropics will be a mess, it will trigger numerous feedbacks, and nature and many human activities cannot adapt at those rates. This could lead to pest invasions, waves of refugees, and wars. All these concerns lead to the idea that 6 degrees [Celsius] in a century could be catastrophic at a first decimal-place probability.

Our Ability to Adapt

There is a clear difference in outlook among the respondents, depending on their assumptions about the ability of society to adapt to climatic changes. One was concerned that society's response to the approaching millennium would be akin to that prevalent during the Dark Ages, whereas another respondent held that the degree of adaptability of human economies is so high that for most of the scenarios the impact of global warming would be "essentially zero." An economist (14) explains that in his view energy and brain power are the only limits to growth in the long run, and with sufficient quantities of these it is possible to adapt or develop new technologies so as to prevent any significant economic costs. This respondent also points out that the time frame over which the climatic changes are expected to take place is sufficient to allow developments of new technologies and other adaptations.

Another respondent (16) elaborated on the role of technology:

> What is missing most is an understanding of the role of technology, of how society will change as technology advances. If we had been concerned with global warming in the 1890s, it would have concerned transportation by horses rather than automobiles. It is impossible to contemplate what society will be like a century from now as technology changes.

Respondent 19 expressed a similar viewpoint:

> Technology will develop to adjust to and accommodate many of the climatic changes and even provide approaches to countering warming effects. However, projecting technological changes a century or two into the future is hazardous at best. All we can really say is that there will be technological changes and that as in the past they will probably offset adverse effects to some degree.

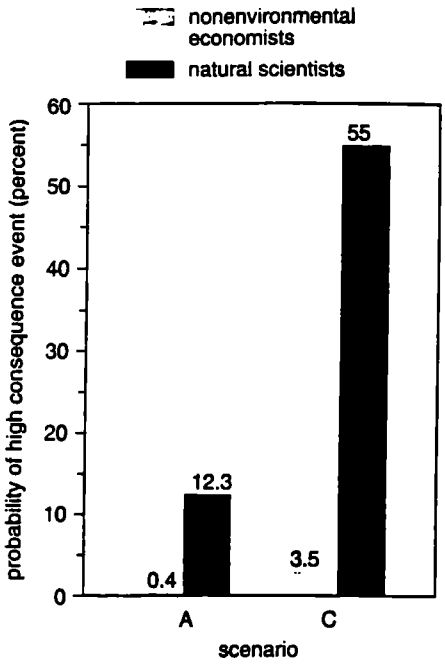

Figure 4. Difference in academic discipline separated those making high estimates of the economic impacts from global warming from those who were comparatively unconcerned. Natural scientists' estimates were 20 to 30 times higher than mainstream economists'.

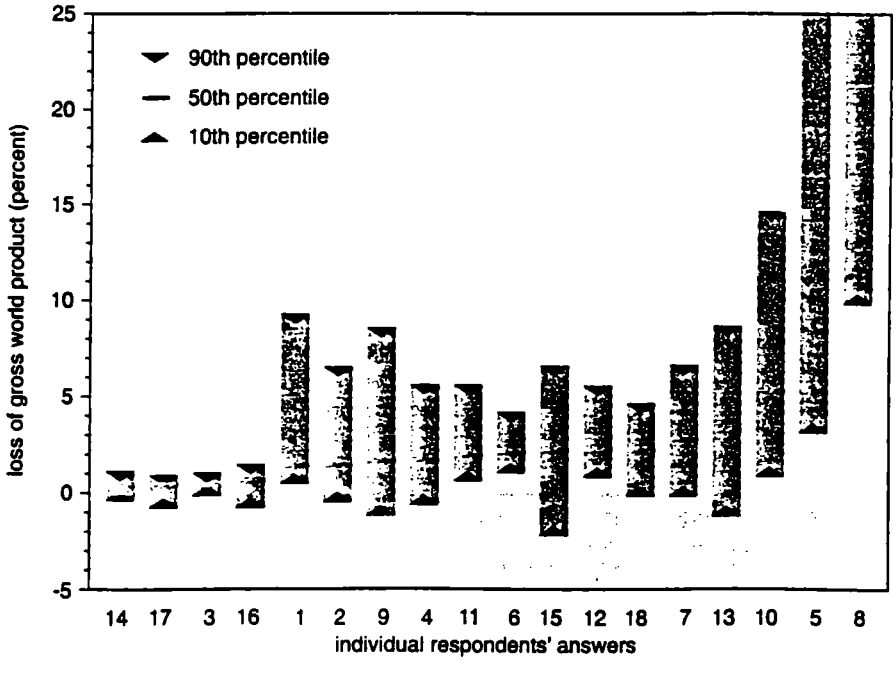

Figure 5. Respondents were queried on the distribution of impacts for scenario A. The 90th percentile is the level of impacts for which a respondent believes that the odds are 9 to 1 that the actual outcome will better. Each respondent's best guess of impacts is shown as the 50th percentile. From the ranges of these estimates can be inferred some measure of each respondent's degree of uncertainty about the economic impact of a 3-degree warming by 2090.

with reservations and a recognition of the inherent difficulty of the task. One respondent (19), however, was a holdout from such guesswork, writing:

> I must tell you that I marvel that economists are willing to make quantitative estimates of economic consequences of climate change where the only measures available are estimates of global surface average increases in temperature. As [one] who has spent his career worrying about the vagaries of the dynamics of the atmosphere, I marvel that they can translate a single global number, an extremely poor surrogate for a description of the climatic conditions, into quantitative estimates of impacts of global economic conditions.

Warming in the Global Perspective

Finally, many of the respondents noted that greenhouse warming is but one of the issues and uncertainties facing civilization in the century to come. Respondent 2 expressed this view as follows:

> "God does not play dice with the universe," was Albert Einstein's reaction to quantum mechanics. Yet mankind *is* playing dice with its natural environment through a multitude of interventions. Depending on one's perspective, it is easy to become either optimistic or pessimistic about our ability to understand and cope with the threat that greenhouse warming poses to our global village. On the one hand, it is true that we are... gambling with our future in more ways than we know. Humans seem just as quarrelsome as they were at the dawn of recorded history, and they have devised new weapons that are awesomely effective at avenging their quarrels. At the same time, our powers of observation and analysis are also orders of magnitude more powerful. The combination of monitoring, measuring, analyzing and computing are growing even faster than our ability to emit greenhouse gases, pollute and cut trees. What will win this race between our tendency to quarrel and pollute and our power to reason and compute? The answer must await the roll of the dice called history.

Survey Participants and Affiliations

Robert M. Adams (anthropology). Secretary of the Smithsonian Institution. Former provost of the University of Chicago. Member of the Synthesis and Science Panels of the U. S. National Academy of Sciences (NAS) Committee on the Policy Implications of Greenhouse Warming (1990–92). Research on the history of irrigation and urban settlements.

Jesse Ausubel (technological and policy sciences). Fellow in Science and Public Policy, Rockefeller University. Staff director of the NAS Carbon Dioxide Assessment Committee (1981–83) and member of the Adaptation Panel of the NAS Committee on the Policy Implications of Greenhouse Warming (1990–92). Research on technology and society.

William Cline (economics). Senior researcher, Institute of International Economics. Author of *The Economics of the Greenhouse Effect* (1992). Research on international economics, the debt crisis and the economics of global warming.

Richard N. Cooper (economics). Professor of economics, Harvard University. Former Undersecretary of State for Economic Affairs and former provost, Yale University. Member of the Synthesis and Mitigation Panels of the NAS Committee on the Policy Implications of Greenhouse Warming (1990–92). Research on international economic cooperation.

Rob Coppock (policy studies and risk analysis). Staff of the NAS. Staff director of the NAS Panel on the Policy Implications of Greenhouse Warming (1990–92). Research on risk analysis.

Daniel J. Evans (structural engineering). Business consultant. Former governor of the state of Washington and former U.S. senator. Chairman of the Synthesis Panel of the NAS Panel on the Policy Implications of Greenhouse Warming (1990–92).

Michael Grubb (energy-policy analyst). Senior research fellow at the Energy and Environmental Program of the Royal Institute of International Affairs, London. Main work in this area is the two-volume work *Energy Policy and the Greenhouse Effect*.

Karl-Goran Maler (environmental economics). Professor of economics at Stockholm Institute of Economics. Author of game-theoretical analysis of problems of negotiating climatic change issues. Research on the economics of environment and development, with a chapter on environment and development for *Handbook of Development Economics, Vol. 2*.

Alan Manne (economics). Professor emeritus of operation research, Stanford University. Chairman of the International Energy Workshop (1981–), participant in the U.S. National Academy of Sciences CONAES (Committee on Nuclear and Alternative Energy Systems) study and in several rounds of the Stanford Energy Modeling Forum. Research on mathematical modeling and energy systems.

Richard Morgenstern (environmental economics). Associate director, U. S. Environmental Protection Agency (EPA). Supervised research and reports on the economic impacts and policy implications of global warming. Economic advisor to the administration of the EPA at the Earth Summit, June 1992.

William D. Nordhaus (economics). A. Whitney Griswold Professor of Economics, Yale University, and author of this article.

Gordon Orians (ecology). Professor of zoology and environmental studies at the University of Washington. Past director of environmental studies. Member of the Synthesis and Adaptation Panels of the NAS Committee on the Policy Implications of Greenhouse Warming (1990–92). Coeditor of *Global Biogeochemical Cycles* (Academic Press, 1992).

David Pearce (environmental economics). Professor of economics at University College, London, and director of the Center for Social and Economic Research on the Global Environment. Advisor to Her Majesty's Government on environmental economics (1989–92). Research on environment and development. Professor Pearce was assisted in responding by Samuel Fankhauser, who has undertaken an extensive survey of estimates of the impact of global warming.

Richard Schmalensee (economics). Professor of economics, MIT. Former member of the President's Council of Economic Advisers. Supervised U. S. government report on the economics of climatic change and coordinated the government's economic policies on climatic change. Research on industrial organization and regulation.

Stephen Schneider (climatology). Professor of biological science, Stanford University. Former head of Interdisciplinary Climate Systems at the National Center for Atmospheric Research. Member of the Synthesis and Mitigation Panels of the NAS Panel on the Policy Implications of Greenhouse Warming (1990–92). Research on climate modeling.

Thomas Schelling (economics). Professor of economics, University of Maryland. Chairman or member of several committees on the implications of global warming and author of a chapter on impact and adaptations for the NAS Carbon Dioxide Assessment Committee (1981–83). Research on game theory, national security and microeconomics.

Lawrence Summers (economics). Professor of economics, Harvard University (on leave) and Undersecretary of the Treasury for monetary affairs (1993–). As chief economist at the World Bank, he supervised studies and the writing of *World Development Report 1992*, which surveyed development and the environment, and interacted with authors and the writing of background papers on the economic aspects of global warming.

Paul Waggoner (meteorology and agricultural science). Distinguished scientist at the Connecticut Agricultural Experiment Station. Former director of the Connecticut Agricultural Experiment Station and chairman of the Adaptation Panel and member of the Synthesis Panel of the NAS Committee on the Policy Implications of Greenhouse Warming (1990–92). Research on climate and agriculture, especially water and pests.

Robert White (atmospheric science and engineering). President, National Academy of Engineering. Former chief, U. S. Weather Bureau, and administrator of the National Oceanic and Atmospheric Administration. Research on general circulation of the atmosphere. Oversight and review of reports on global environmental issues.

The 1995 IPCC Report:

Broad Consensus or "Scientific Cleansing"?[1]

article for *Ecofables/Ecoscience*

by

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In the spring of 1996, the Intergovernmental Panel on Climate Change (IPCC) released its Second Assessment Report (SAR) on the question of human impacts on the global climate system.[2] Like past IPCC assessments, the SAR had three parts: climate science (Working Group I), impacts of climate change (Working Group II), and economic and social dimensions (Working Group III).

The Global Climate Coalition (an energy industry lobby group) and a number of self-proclaimed "contrarian" scientists immediately launched a major, organized attack designed to discredit the conclusions of Working Group I as expressed in the SAR. They claimed that the IPCC had inappropriately altered a key chapter for political reasons. They alleged that the IPCC had "corrupted the peer review process" and violated its own procedural rules.

These accusations ignited a major debate — widely reported in the press — lasting several months. Were the charges true?

THE IPCC SECOND ASSESSMENT REPORT

The IPCC is an office of the United Nations Environment Programme and the World Meteorological Organization. Its evaluates and synthesizes the scientific understanding of global climate change for national governments and United Nations agencies. Its goal is fairly to represent the full range of credible scientific opinion and, if possible, to identify a consensus view on the most likely scenario(s) within this range. The IPCC's reports are intensively peer-reviewed. They are generally regarded as the single most authoritative source of information on climate change and its potential impacts on environment and society.

Like all IPCC assessments, the SAR contained three "Summaries for Policymakers" (SPMs), one for each of the IPCC's three Working Groups. Since the full SAR stretches to well over 2,000 pages of mostly dense technical prose, few outside the scientific community are likely either to read it in its entirety or to understand most of its details. Therefore, these summaries tend to become the basis for press reports and public debate.

For this reason, the Working Groups consider their exact wording with extreme care before they are published. At the end of the IPCC report process, they are approved *word for word* by national government representatives at a plenary meeting attended by only a fraction of the lead authors.

The SPM for Working Group I, which assesses the state of the art in the physical-science understanding of climate change, contained the following now-famous paragraph:

> Our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors. These include the magnitude and patterns of long–term natural variability and the time–evolving pattern of forcing by, and response to, changes in concentrations of greenhouse gases and aerosols, and land surface changes. *Nevertheless, the balance of evidence suggests that there is a discernible human influence on global climate.* (Italics added.)[3]

Three-quarters of this paragraph consists of caveats about uncertainties and limitations of current understanding. Nonetheless, it marked the first time the IPCC had reached a consensus on two key points: first, that global warming is probably occurring ("detection"), and second, that human activity is more likely than not a significant cause ("attribution"). Like this summary paragraph, the body of the report discussed — frequently and at length — the large scientific uncertainties about attribution. The Working Group carefully crafted the "balance of evidence" sentence in the SPM to communicate the strong majority opinion that despite these uncertainties, studies were beginning to converge on a more definitive answer to the attribution question.

The SAR was fraught with political significance. Official publication of the full report occurred in early June, 1996. At that point the Second Conference of Parties (COP-2) to the 1992 Framework Convention on Climate Change was about to meet in Geneva. A sea change in American climate policy was widely rumored. Since the Reagan administration, official U.S. policy had sanctioned only voluntary, non-binding emissions targets and further scientific research. If the United States were to abandon its resistance to binding emissions targets, a strong international greenhouse policy would become much more likely. Since the more-research, no-binding-targets position was officially based on assertions of high scientific uncertainty, the SAR's expressions of increased scientific confidence were viewed as critical.

The rumors proved correct. On July 17, 1996, U.S. Under-Secretary of State for Global Affairs Tim Wirth formally announced to COP-2 that the United States would now support "the adoption of a realistic *but binding* target" for emissions. The exact degree to which the IPCC SAR influenced this policy change cannot be known. But Wirth certainly gave the impression that the report was its proximate cause. He noted in his address that "the United States takes very seriously the IPCC's recently issued Second Assessment Report." He then proceeded to quote the SAR at length, proclaiming that "the science is convincing; concern about global warming is real."[4]

"A Major Deception on Global Warming"

On June 12, 1996, just days after formal release of the IPCC SAR and scant weeks before the COP-2 meeting in Geneva, the *Wall Street Journal* (WSJ) published an op-ed piece entitled "A Major Deception on Global Warming."The article was written by Frederick

Seitz, President Emeritus of Rockefeller University. Seitz is not a climate scientist but a physicist. Nevertheless, his scientific credentials are formidable. He is a recipient of the National Medal of Science and a past President of both the National Academy of Sciences and the American Physical Society.

In his article, Seitz accused some IPCC scientists of the most "disturbing corruption of the peer-review process" he had ever witnessed.[5]

Seitz's Accusations

Seitz's proclaimed distress stemmed from the fact that the lead authors of the SAR's Chapter 8 — on detection and attribution — had altered some of its text *after* the November, 1995 plenary meeting of Working Group I (WGI), in Madrid, at which time the chapter was formally "accepted" by the Working Group. According to Seitz, since the scientists and national governments who accepted Chapter 8 were never given the chance to review the truly final version, these changes amounted to deliberate fraud and "corruption of the peer-review process." Not only did this violate normal peer review procedure, Seitz charged; it also violated the IPCC's own procedural rules.

Quoting several sentences deleted from the final version of the chapter, Seitz argued that the changes and deletions "remove[d] hints of the skepticism with which many scientists regard claims that human activities are having a major impact on climate in general and on global warming in particular." Without directly attributing motives, Seitz implied that the changes had been made in the interests of promoting a particular political agenda. Seitz said that Benjamin D. Santer, lead author of Chapter 8, would have to shoulder the responsibility for the "unauthorized" changes. Seitz was not present at the IPCC meetings. He did not contact Santer or anyone else at the IPCC to verify that the changes were indeed "unauthorized" before publishing his op-ed piece.

Responses from Santer and the IPCC

Santer responded immediately, in a letter co-signed by some 40 other IPCC officials and scientists (myself among them - SHS). They said that Seitz had misinterpreted the IPCC rules of procedure. Rather than being "unauthorized," they wrote, the post-Madrid changes were in fact *required* by IPCC rules, under which authors must respond to comments submitted during peer review or arising from discussions at the meetings.[6]

Commentators at the Madrid meeting had advised making changes to Chapter 8 for two reasons. First, they urged clarification of the meaning and scientific content of some passages in accordance with the recommendations of reviewers (including some criticisms introduced at the Madrid meeting itself). Second, they thought the structure of the chapter should be brought into conformity with that of other SAR chapters. In particular, a "Concluding Summary" was removed from the final version, since no other chapter contained a similar section. (Chapter 8, like all the rest, already had an "Executive Summary.") Sir John Houghton, in his capacity as co-chairman of WGI, specifically authorized the changes.

Santer, in consultation with other Chapter 8 authors, made the suggested changes in early December. The entire SAR, including the newly revised Chapter 8, was "accepted" by the full IPCC Plenary at Rome later than month.

Santer made the changes himself, and the final version of the chapter was not reviewed again by others. However, as he and his colleagues continually stressed, this procedure was the normal and agreed IPCC process. Santer et al. pointed out that no one within the

IPCC objected (or had ever objected) to this way of handling things. Replying separately in support of Santer and his colleagues, IPCC Chairman Bert Bolin and WGI Co-Chairmen John Houghton and L. Gylvan Meira Filho quoted the official U.S. government review of Chapter 8, which stated explicitly that "it is essential that... the chapter authors be prevailed upon to modify their text in an appropriate manner following discussion in Madrid."[7]

Further Exchanges

The WSJ op-ed was not the first time charges of suppression of scientific uncertainty in Chapter 8 had been aired. On May 22, a few days before the Seitz op-ed appeared, the small journal *Energy Daily* reported the same allegations in considerably greater detail.[8] The *Energy Daily* article also reported their source: a widely circulated press release of the Global Climate Coalition (GCC, an energy industry lobby group).

In its June 13 issue, the prestigious science magazine *Nature* also reported on the GCC allegations.[9] The *Nature* report, unlike the Seitz and *Energy Daily* articles, included explanations of the revision and review process from Santer and the IPCC. Under the hot-button headline "Climate report 'subject to scientific cleansing,'" an accompanying editorial argued that the GCC analysis was politically motivated and generally false. But the editorial also noted that the Chapter 8 changes may have resulted "in a subtle shift... that... tended to favour arguments that aligned with [the SAR's] broad conclusions."[10]

The WSJ op-ed set off a lengthy chain of exchanges lasting several months. The main participants in the public controversy were Seitz, Santer, other Chapter 8 authors, the Chairmen of the IPCC (Sir John Houghton and Bert Bolin), and climate-change skeptics S. Fred Singer and Hugh Ellsaesser. Singer, in particular, made the charges of political motivation explicit. In a letter to the *Wall Street Journal,* he wrote that Chapter 8 had been "tampered with for political purposes." The IPCC, he claimed, was engaged in a "crusade to provide a scientific cover for political action."[11]

Semi-privately, in electronic mail exchanges involving many additional participants (and widely copied to others), the debate became intense and sometimes quite bitter. Santer, who felt forced to defend himself, spent the majority of his summer time responding to the charges. Previously a quiet, private man known to scientists primarily as a proponent of the rigorous use of statistical methods, Santer rapidly became a public figure, submitting to dozens of interviews. The drain on his time and energy during this period kept him from his scientific work, he said.[12]

Both the public and the private exchanges themselves became objects of further press reports, widely disseminated by the news wire services. As they went on, the debate spread from the initial issues about peer review and IPCC procedure to include questions about the validity of Chapter 8's scientific conclusions. Even before the report was formally published, climate-change contrarians had claimed that Chapter 8 dismissed or ignored important scientific results that disconfirmed the global warming hypothesis. They argued that the allegedly illegitimate changes to Chapter 8 made this problem even more acute.[13]

DID THE CHAPTER 8 AUTHORS VIOLATE IPCC RULES?

Seitz, the GCC, and others accused the authors of Chapter 8 of fraud on two counts. First, they alleged that the changes made to Chapter 8 after the final IPCC plenary violated the

IPCC's own rules of procedure. Second, and more seriously, they charged them with violating the fundamental standards of scientific peer review. In this section, we argue that IPCC rules were not violated in the case of Chapter 8. In addition, weargue that *in practice* the process correctly reflects the essential tenets of peer review. However, we also show that the IPCC rules do not specify adequate closure mechanisms for the report drafting process. We demonstrate that the two-level certification process ("acceptance" and "approval" of IPCC documents) is poorly specified as well, and can even invite misinterpretation by determined critics.

In their responses to the Seitz/GCC charges, the Chapter 8 authors claimed that IPCC rules *required* them to make the changes advised immediately before and during the Madrid WGI Plenary. Analysis of the IPCC rules suggests that the real situation is more ambiguous. Yet they had three very good reasons for believing this to be the case.

First, the rules require authors to respond to commentary, to the best of their ability and as fully as possible.[14] Working Group co-chairs have broad discretion to define this process and set time limits for it. Nowhere do IPCC rules explicitly address the question of when a report chapter becomes final (i.e., when all changes must cease). Therefore, Santer et al. correctly understood that the Working Group Chairs and the Plenary meeting itself would define the endpoint of the revision process.

Second, report chapters are "accepted" rather than "approved." Acceptance constitutes IPCC certification that *the drafting and review process has been successfully completed.* It is an expression of trust in the authors and the process, and is explicitly distinguished from "approval," or detailed review on a line-by-line basis. Operating under these definitions, the IPCC Plenary "approved" the WGI Summary for Policymakers (SPM), but "accepted" Chapter 8. In other words, Plenary acceptance did not imply word-for-word review of the chapter. Instead, it indicated trust that the authors had responded appropriately and sufficiently to the review process. Therefore, the Chapter 8 authors believed that the rules permitted them to make changes when explicitly requested to do so by the IPCC Plenary, or in response to peer comments received at or immediately prior to the Plenary.

Third, no IPCC member nation has ever seconded the Seitz/GCC objections.[15] (Ninety-six countries were represented at the Madrid plenary.) From this, above all, we can safely infer that Santer et al. proceeded exactly as expected.

Santer et al. believed that they were following IPCC rules, and this made perfect sense within the well-established informal culture of the IPCC. However, a careful reading of the IPCC's *formal* rules reveals that in fact the rules *neither allow nor prohibit* changes to a report after its formal acceptance. The legalistic Seitz/GCC reading of the rules is not, therefore, completely implausible — even if it was, as we believe, primarily a smokescreen to divert attention from the clear consensus that attribution could no longer be considered unlikely.

Our analysis suggests a significant flaw in the rules as currently written. While "approved" documents (the SPMs) clearly must not be altered once approved, there is no precisely defined closure mechanism for "accepted" documents (full-length Working Group reports and their constituent chapters).[16] The Seitz/GCC attack has effectively demonstrated that a hybrid science/policy organization like the IPCC needs better, more explicit rules of procedure. This minor virtue aside, however, the Seitz/GCC reading violates the spirit and intent of the IPCC process.

The IPCC is run by scientists. Its participants think of it primarily as a scientific body. By the standards of many political organizations, its formal rules are not very extensive. They are also not very specific. They purposely leave undefined the meaning of key terms such as "expert" and important processes such as "taking into account" comments. Under the rules, Lead Authors carry full responsibility for report chapters, and the IPCC leadership retains very broad discretion, subject to Plenary "acceptance" and "approval" by national governments.

There are good reasons for this arrangement. Formal procedures are relatively unimportant in scientific culture. This is true because scientists belong to very small social groups endowed with extremely strong and deeply entrenched (informal) norms. In addition, since scientific methods and results are constantly changing, too much focus on formal rules would inhibit progress. Likewise, formal rules are not very important in the day-to-day functioning of the IPCC. Instead, *informal rules based on the everyday practices of scientific communities* guide the bulk of the work.

Maintaining this informality is quite important for effective scientific work. Yet it is not without dangers, especially in a situation where almost any scientific finding can have political implications. Just as in any other politicized realm, without clear procedures to ensure openness and full rights of participation, dissenters may find — or believe they have found — their voices ignored. One of the IPCC's most important features is its openness and inclusivity; balancing this against scientific informality will require constant vigilance, and perhaps a reconsideration of the formal review process.

From the point of view of *political* legitimacy, then, acceptance of reports before final revision is clearly a risky proposition. But from the viewpoint of scientific legitimacy, ongoing revision is a normal feature of the research cycle. Even after a multi-stage review process, minor flaws can be found and improvements added. This is not unlike the common situation in which an author makes minor changes to the galley proofs of a manuscript — changes not subject to peer review. Thus, in the case of the IPCC, adding a final approval stage to the already long and cumbersome review process would be unlikely to add significantly to the scientific credibility of the final result. While it needs to revise its rules to better protect itself from accusations of political capture, the IPCC must also, at all costs, avoid becoming a science-stifling, inflexible bureaucracy.

DID THE CHAPTER 8 REVISIONS "CORRUPT" THE PEER REVIEW PROCESS?

One of the most important informal, everyday practices of science is peer review. Seitz and the GCC accused the IPCC of violating this standard, too. Were they right?

In a typical peer review procedure, scientists write articles and submit them to a scientific journal. The journal editor sends the article to several referees, all of them experts in the authors' field ("peers"). Most peer review is "blind," meaning that referees do not know the authors' identity. (Not all journals conform to this standard.) In most cases, the referees' identity is kept secret from the author. However, some journal editors, like myself (SHS), encourage referees to reveal themselves. Since many scientific communities are quite small, referees and authors can often guess each other's identity.

Referees may recommend acceptance, rejection, or acceptance after certain specified changes are made ("revise and resubmit"). The last of these responses is by far the most common. The authors then rewrite their article in response to the reviewers, and the editor serves as referee. The process usually goes back and forth several times, with several

rounds of revision, until a suitable compromise is achieved among reviewers, authors and the editor. A similar process is normally applied to grant proposals.[17]

To decide whether Chapter 8 "corrupted" this process, let's look at how it worked in IPCC Working Group I (WGI). In July of 1995, the third installment of the WGI drafting and review process for the SAR took place in Asheville, North Carolina. This meeting, like all other IPCC processes, was characterized by exceptional openness to critique, review, and revision. About six dozen climate scientists from dozens of countries took part. The meeting was designed to make explicit the points of agreement and difference among the scientists over exceedingly controversial and difficult issues, including Chapter 8 — the most controversial.

New lines of evidence had been brought to bear by three climate modeling groups around the world, each suggesting a much stronger possibility that a climate change signal has been observed and that its pattern (or fingerprint) is matched to anthropogenic changes. Ben Santer, as the Convening Lead Author of Chapter 8, had assembled the results of a number of modeling groups. He presented the results of his group's effort not just to Chapter 8's Lead Authors and contributors, as is typical in IPCC meetings, but to the entire scientific group assembled at Asheville.

In this setting, Santer had to explain this work not only to his most knowledgeable peers, but also to scores of others from diverse scientific communities. These included stratospheric ozone experts like Susan Solomon and Dan Albritton, satellite meteorologists like John Christy, and biosphere dynamics experts such as Jerry Melillo. Climatologists such as Tom Karl and I (SHS) were also present, along with the heads of national weather services and other officials from several countries who served on the IPCC's assessment team.

Not everybody was equally knowledgeable on the technical details of the debate, of course. Perhaps only 25 percent of those assembled had truly in-depth knowledge of the full range of details being discussed. However, all understood the basic scientific issues and most know how to recognize slipshod work -- to say nothing of a fraud or a "scientific cleansing" -- when they see it. Even the less familiar participants thus served an essential role: they acted as technically-skilled witnesses to the process of honest, open debate.

This remarkable session lasted for hours. (In fact, it was continued after dinner by roughly a dozen scientists, who spent nearly three hours discussing the final paragraph of the "Detection Section" of the Summary for Policymakers.)[18] Though occasionally intense, it was always cordial, never polemical. As a result, the wording of Chapter 8 was changed. Ideas and concepts were somewhat altered, but basic conclusions by and large remained unchanged — because the vast bulk of those assembled were convinced that the carefully hedged statements the lead authors proposed were, in fact, an accurate reflection of the state of the science based upon all available knowledge, including the new results.

This was peer review at ten times the normal level of scrutiny! It would be practically inconceivable for the editor of a peer-reviewed journal to duplicate this process. A few referees and an editor can only hope to execute the reviewing role a fraction as well as the remarkable, open process at Asheville. Moreover, after the Asheville meeting, two more IPCC drafts were written and reviewed by hundreds of additional scientists from all over the globe.

An Open Process of Scientific Debate: Witnessing in Action

At Madrid, Santer presented Chapter 8's conclusions to the national delegates of 96 IPCC member nations. The conclusions were not presented alone, but followed a presentation to the plenary session of the scientific evidence contained in Chapter 8. Nevertheless, several countries objected to the Chapter 8 conclusions. Most of the objections came from OPEC or less-developed nations. One delegate, from Kenya, moved to have the chapter entirely dropped from the final report.

In response, the meeting's chair — following procedures often used at IPCC Plenary meetings to resolve disputes — called for a drafting group to revise the chapter as well as and the detection and attribution section of the Summary for Policymakers. Nations complaining about the Chapter 8 draft were invited, indeed expected, to meet with Lead Authors, first to discuss the scientists' point of view and then to fashion new, mutually acceptable language.

This breakout group worked for the better part of a day. Delegates from over half a dozen countries — including the Kenyan who had publicly advocated dropping the chapter — met with about half a dozen Chapter 8 authors, including Santer, co-Lead Author Tom Wigley, and scientists Kevin Trenberth, Michael MacCracken, John Mitchell, and me (SHS). The Kenyan sat next to me. Initially, he was confused by the discussion and somewhat hostile. We had many side conversations about what was being discussed: models, data, statistical tests and various climate forcing scenarios. Although he was not a front-rank climate researcher, this delegate was a trained scientist. He began to grasp the nature of the Lead Authors' arguments, listening carefully to about half of the breakout meeting.

Ironically, the Saudi Arabian delegation sent no representative to this most controversial drafting group, even though Saudi Arabia had led the opposition in the plenary meeting. During the Chapter 8 debate, Saudi delegates often issued objections soon after receiving notes from the Global Climate Coalition representative. (Non-governmental organizations were also represented at Madrid. For example, S. Fred Singer — President of the Science & Environmental Policy Project and a self-proclaimed contrarian — raised a number of issues from the floor.)

Later in the plenary meeting, when Santer presented the drafting group's revised text, the Saudi delegates once again objected. Santer forcefully challenged them. Why, he asked, had no Saudi attended the breakout group — if their objections had some basis in science? The head Saudi delegate haughtily announced that he didn't have to account for his decisions about which drafting group to attend. Besides, he said, his was "only a small delegation" of a few people.

At this point the Kenyan delegate rose to speak. (I held my breath.) "I'm a member of a small delegation too," he said. (He was the only Kenyan representative.) "But somehow I managed to attend this most important drafting session. As a result, I am convinced that Chapter 8 is now well written and I have no objections to its inclusion in the report." (I paraphrase his words from memory.) The impact of his intervention was stunning, stopping with a few words what appeared to be a mounting movement of OPEC and LDC opposition to Chapter 8 before it could garner any further support.

Later on I privately congratulated the Kenyan for having the courage to object publicly, observe privately, and then re-evaluate his position before the entire plenary. He said he wasn't sure his country would approve of his stance, but having witnessed the debate process for several hours, he had become convinced it was honest and open. That was all he needed to change his opinion from preconceived skepticism to support of the Lead Authors' conclusions.

What this courageous delegate did *was the essence of good science.* He allowed his initial hypothesis to be subjected to new evidence, tested it, and found it wanting. He then listened to arguments for a different point of view, subjected them to the tests of evidence and debate, and reached a new conclusion.

Contrast this open IPCC process with that of the critics led by Seitz and the Global Climate Coalition. The latter first presented their technical counter-arguments in such "refereed scientific literature" as the editorial pages of the *Wall Street Journal.* Some even had the temerity to allege (falsely) that Chapter 8's conclusions were based upon non-peer-reviewed articles.[19] The Seitz/GCC group charged that the minor changes made to Chapter 8 during the post-Madrid revision process had somehow dramatically altered the report. Without a shred of evidence, Singer and others asserted that the changes were politically motivated "scientific cleansing."

These irresponsible claims were not reviewed by a single independent, expert peer before being published — in the opinion pages of a business daily and a few news magazines. We leave it to readers to decide which are more credible: the reports of the IPCC, submitted to many rounds of extremely public, intensive peer review, or the op-ed pieces and pamphlets of Seitz, Singer, and the GCC.

WHAT ABOUT THE SCIENCE?

In a nutshell, the new evidence reported to IPCC and later published in *Nature* was based not upon new empirical or theoretical results, but on new ways of asking climate models the right questions.[20] In the past, critics such as the University of Virginia's Pat Michaels had correctly argued that direct observational evidence of global warming effects (i.e. "signals") in the climate record were not very well matched to CO2-only model results. For example, CO2-only models suggested that the Earth should have warmed up 1°C rather than the one-half degree C observed in the last century. Additionally, CO2-only models suggested that the Northern Hemisphere would warm up more than the Southern Hemisphere. Such models also, however, suggested the stratosphere would cool as greenhouse gases increased. This clearly *was* happening (although at least part of that cooling can be attributed to stratospheric ozone depletion).[21]

The Earth's warming of a half degree C during the 20th century could be explained simply by asserting the trend to be a natural fluctuation in the climate. The IPCC scientists attempted to estimate the likelihood that natural events were responsible for the observed surface warming. They concluded that this was possible, but improbable. Critics, meanwhile, simply asserted that the warming was natural, without characterizing the probability that this was the correct explanation. Even if it did go unchallenged in a number of op-ed articles, this is a scientifically meaningless claim.

What is the probability that a half-degree warming trend in this century is a natural accident? This cannot be answered by looking at the thermometer record alone, since a globally averaged record is not reliable for much more than a century, if that. It is like trying to determine the probability of "heads" in a coin flip by flipping it once. Instead, climate scientists look at proxy records of climate change over long periods of time, such as fluctuating time series of tree ring widths, the deposits left from the comings and goings of glaciers, and the fluctuations of various chemical constituents in ice cores. These records, while not direct measurements of global temperatures, are nonetheless proportional to components of the climate in different parts of the world, and provide a rich record of natural variability.

This record (as summarized in Chapter 3 of the SAR) suggests that the warming of the last century is not unprecedented.[22] But it also is not common. Perhaps once in a millennium, such proxy records suggest, a half-degree C global century-long trend could occur naturally.[23] In my judgment (SHS), this circumstantial evidence implies that a global surface warming of half a degree has about an 80 to 90 percent likelihood of *not* being caused by the natural variability of the system.

Natural climatic forcing factors, such as energy output changes on the sun or peculiar patterns of volcanic eruptions, could cause the observed climate trend. However, each of these climate forcings has a peculiar signature or fingerprint. For example, energy increases from the sun would warm the surface, the lower atmosphere, and the stratosphere all at the same time. On the other hand, greenhouse gas forcing would cool the stratosphere while warming the troposphere. Aerosols from human activities, particularly the sulfates generated in coal- and oil-burning regions of the US Northeast, Europe, and China, would cool the troposphere mostly during the day and not at night, and would largely cool the Northern Hemisphere, especially in the summertime when the sun is stronger.

This aerosol effect has turned out to be very important. Indeed, adding sulfate aerosols to greenhouse gas increases in the models led to a dramatic boost in the confidence that could be attached to the circumstantial evidence associated with climatic fingerprints. That is, when the models were driven by both greenhouse gases globally, and sulfate aerosols regionally, no longer did the Northern Hemisphere warm up more than the Southern Hemisphere, or all parts of the high latitudes substantially more than the low latitudes. Instead, a different fingerprint pattern emerged. Moreover, this pattern in the models showed an increasing correlation with observations over time — precisely what one would expect in a noisy system in which the human forcing increases with time. By itself, the pattern still has roughly a 10 percent chance of being a random event. However, when taken together with good physical theory and knowledge of ice age-interglacial cycles, seasonal cycles, volcanic eruptions, and now more consistent fingerprints, the vast bulk of the scientific community felt it was not irresponsible to assert that there was a higher likelihood that human climate signals had been detected. This is the basis for Chapter 8's now-famous claim that "the balance of evidence suggests a discernible human influence on climate."

At this point in the evolution of knowledge about the Earth's climate system, this is no longer a radical statement. It reflects a lowest-common-denominator consensus view of the vast majority of scientists. It does *not* say that a climate warming signal has been detected beyond any doubt. Neither we nor any other responsible scientists would make such a claim. But it does offer good reason to begin to plan, responsibly, for the possibility — which we now see as more likely than not — that the global climate will warm by at least one or two degrees during the next 50 years.

HOW SHOULD WE RESPOND TO CLIMATE-CHANGE CONTRARIANS?

To ignore contrarian critics would be inappropriate. Occasionally, non-conventional outlier opinions revolutionize scientific dogma (Galileo and Einstein being the most oft-cited examples). However, we believe that news stories are grossly misleading and irresponsible if they present the unrefereed opinions of contrarians as if they were comparable in credibility to the hundred-scientists, thousand-reviewer documents released by the IPCC. The general public cannot be relied upon to determine for themselves how to weigh these conflicting opinions. And to publish character-

assassinating charges of "scientific cleansing" without checking the facts is simply unethical — at least in any system of ethics we respect.

The journalistic doctrine of "balance", while perhaps appropriate in two-party political systems where the "other side" must always get its equal coverage, is inappropriate if applied literally to multifaceted scientific debates. In climate science, wide ranges of probabilities are attached to a whole array of possible outcomes.[24] Scientific controversy simply can't be trivialized into a false dichotomy between those who assert that human effects are likely to produce a catastrophic, "end of the world" crisis, "balanced" against those who assert that at worst nothing will happen and at best it will all be good for us. "The end of the world" and "no impact at all" are *the two lowest-probability cases.*

This is not just a problem for journalists. It also affects scientists. In communication with the public, we sometimes tend to focus our attention on controversies at the cutting edge of the art, rather than present clear perspectives on what is well understood — separating what is truly known from what is merely probable and both of these from what is highly speculative. This, combined with the propensity of the media to focus on "dueling scientists" and extreme, outlier opinions, leads to a miscommunication of the actual nature of the scientific consensus.[25]

This consensus is vital to the policy process. In essence, the policy question is to decide how much of current resources should be invested as a hedge against potential negative outcomes. This clearly is a value judgment. It is precisely the kind of judgment that the public and the policy establishment should make, but it can only be made if the decisionmakers — who are not, and are not going to become, experts — are aware of the best range-of-probability and range-of-consequences estimates of the responsible scientific community.

Faxes sent by special interests to every major journalist on the planet or every significant elected and unelected official — what we like to call the "one fax, one vote" syndrome — are not very good sources of truth. Vastly better is the work of groups such as the IPCC and the National Research Council, which although slow, deliberative, sometimes snobby, and occasionally dominated by strong personalities, are nonetheless the best representation of the scientific community's current general opinion.

This kind of scientific consensus is not the same thing as "truth." Once in a while, the contrarians are right. Indeed, we are certain that some aspects of the current vision of climate change will turn out to be of minor impact, while others will prove to be more serious than currently thought. That is why assessment needs to be a continuous process, and why all policymaking requires "rolling reassessment." The IPCC, or its progeny, need to be reconvened every five years or so. Only with this input can the political process legitimately decide, and re-decide, to crank up its efforts at mitigation — or to crank them back down, depending upon what is learned in each new assessment about the climate system, the impact of climate change on environment and society, and the distribution of mitigation costs. This ongoing and open process of refinement of knowledge is the only way that a complex system can become adaptive. Only an adaptive system can minimize the likelihood of making major mistakes, either by overinvesting in environmental protection or by allowing nasty experiments to be performed on Laboratory Earth without any attempt to anticipate or slow down the potential negative, irreversible consequences.[26]

NOTES

[1] The authors wish to thank Simon Shackley, Ben Santer, and Michael Oppenheimer for their helpful comments on a draft of this article.

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Degrees of Certainty

STEPHEN H SCHNEIDER

Debate in the media over global warming often mixes what is well known with what is speculative, thereby leading to an artificially confusing impression that scientists share no consensus of the probable magnitude, timing, and potential seriousness of the environmental and societal consequences of the documented and well-understood buildup of various greenhouse-enhancing gases in the atmosphere. Indeed, widespread concern exists over the plausibility of temperature increases of 1 to 5°C in the 21st century, and that the mid to upper part of that range could imply dramatic restructuring of ecosystems or communities. I discuss the difficulty in interpreting the 0.5 ± 0.2°C 20th century warming trend as "proof" of greenhouse-gas–induced global warming in light of possible climatic-change causal factors such as industrial aerosols, natural fluctuations, or changes in solar output. How to act is controversial, and economic model results showing potential abatement costs of carbon taxes are discussed.

SCIENTISTS TOO OFTEN SHARE RESPONSIBILITY with the media for not clearly communicating complex science issues to the public. Most members of the general public, as well as many officials in government, do not recognize that most scientists spend the bulk of their time arguing about what they do not know. Most scientists consider discussions of well-accepted, proven ideas as "old hat" and not worth our time. That attitude is not without merit, however, for the scientific method operates on the basis of constant questioning, particularly for issues that are not yet well-validated. But if the public and its representatives do not understand our process and its focus on not-yet-resolved issues, they will not easily interpret what has been called the "dueling scientists" debate over global warming, regardless of whether the scientists are ideologically driven. We simply have to spend more time making clear the distinctions among what is well-known and accepted by most knowledgeable scientists, what is known with some degree of reliability, and what is highly speculative.

The public debate on global warming rarely separates those components, thereby leaving the false impression that somehow the scientific community is in overall intellectual disarray. In fact, the 15-year-old often-reaffirmed U S National Academy of Sciences consensus estimate of 1.5 to 4.5°C global average warming if CO_2 were to double still reflects the best estimate from a wide range of current climate models[8] and ancient climatic eras.[7] The Earth has not been >1 to 2°C warmer than now during the 10 000-year era of human civilization. The previous ice age, in which mile-high ice sheets stretched from New York to Chicago to the Arctic, was "only" 5°C colder than the current 10 000-year-old interglacial epoch we now enjoy. This 1.5 to 4.5°C warming range still includes those studies that recently halved the best guess on warming from >4°C to 2.5°C. Perhaps some new discovery next week will push it back up again, but even if not, that enduring 1.5 to 4.5°C warming consensus still remains.

Changes of this magnitude could dramatically alter accustomed climatic patterns, affecting agriculture, water supplies, disease patterns, ecosystems, endangered species, severe storms, sea level, and coastal flooding.

Unless scientists communicate what they know along with what they do not know, the public policy process is subverted in an endlessly confusing debate that inadequately represents the actual nature of informed opinion. It is difficult for the media to do what sometimes I wish they would: back off their concept of "balance" in favor of the concept of "perspective." If an issue is complicated, it is not enough to give equal inches or minutes to "all sides"—a practice that often leaves the public more confused than before,

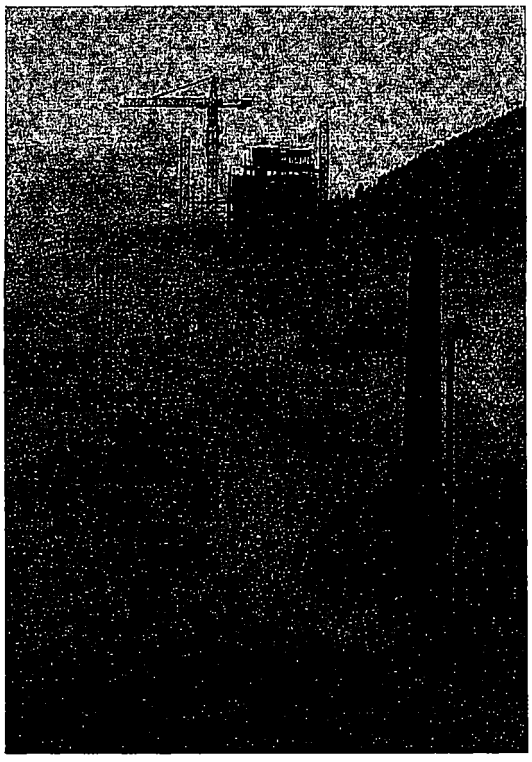

Figure 1.
Qingdao, Shandong Province, People's Republic of China, 1987. In 1898, China ceded Qingdao to Germany for 99 years, along with the right to build the Shandong railway and to work the coal mines for 14 km on either side of the railway line.
BRUCE DALE

CFC = chlorofluorocarbons
CH_4 = methane
CO_2 = carbon dioxide
H_2O = water
N_2O = nitrous oxide
SO_2 = sulfur dioxide

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particularly if the "sides" that are left out are the middle: the bulk of experts, ie, the people who created the established consensus.

Moreover, that established consensus must be stated in terms of probabilities, because very few scientists—myself included—would say they believe the future climate will be in or out of the 1.5 to 4.5°C warming range for certain. Rather, most believe this range to be reasonably probable. Therefore, if scientific opinion is to be communicated accurately, it must be by converting issues into probabilistic terms and providing perspective on the range of views rather than by conducting an entertaining but misleading debate among the most extreme of the dueling scientists—or occasionally stretched beyond caricature in editorials or articles by polemicists and ideologues. What counts, then, is the nature of the evidence and the spectrum of opinions of a broadly representative group of experts,[eg,8,13] not simply a few highly visible debaters with extreme views.

What Does Comprise a Consensus on Global Warming?

Just to illustrate the point that much is already known, I offer the following list of global-warming–related points accepted by a very large fraction of the relevant expert communities. One good source for discussion on the following points is the recent National Research Council's study on global warming and its implications.[13] (Following each of these statements is my own estimate of the likelihood of the statement turning out to be true.)

- ▶GREENHOUSE GASES—H_2O, CO_2, CH_4, N_2O, CFC—trap infrared radiative energy in the lower atmosphere. ▶ CERTAIN
- ▶THE NATURAL GREENHOUSE EFFECT from clouds, water vapor, CO_2, and CH_4 is responsible for some 33°C of natural surface temperature warming. ▶ CERTAIN
- ▶HUMANS HAVE ALTERED the natural greenhouse effect by adding 25% more CO_2, 100% more CH_4, and a host of other greenhouse gases such as N_2O and CFC since the Industrial Revolution. ▶ CERTAIN
- ▶ADDED GREENHOUSE GASES from human activities should have added some 2 to 3 W of infrared radiative energy over every square meter of Earth. This is well-established based on our considerable knowledge of the structure of the atmosphere and on extensive validation from satellites and other measurements—even though the extra 2 to 3 W cannot be directly measured yet. ▶ VIRTUALLY CERTAIN
- ▶EARTH HAS IN FITS AND STARTS, warmed up by ~0.5°C over the past century; the 1980s is the warmest decade on record and 1990, 1991, and 1988 (in order) the warmest years on record. (The warmth of individual years varies with instrument method used—eg, these records are from the surface network of thermometers, not radiosound or satellite instruments.) ▶ VERY LIKELY
- ▶ALTHOUGH NO HIGHLY SIGNIFICANT (ie, at the often-cited 99% statistical confidence limit) cause-and-effect statements between the observed warming and the buildup of human-induced greenhouse gases can be credibly asserted for at least another decade or 2, the likelihood that the 0.5°C 20th century warming trend is wholly a natural phenomenon is small (ie, I would estimate perhaps a 10 to 20% chance). ▶ LIKELY
- ▶MOST CLIMATIC MODELS PROJECT A WARMING of several degrees or so in the next 50 years given standard ("business as usual") greenhouse-gas emission scenarios, and they portend a potential long-term (ie, AD 2100 to 2200) warming commitment as high as 5 to 10°C (eg, IPCC[8]). ▶ GOOD CHANCE, AT LEAST AN EVEN BET

- Natural, *sustained, globally averaged* rates of surface air-temperature change (eg, from the breakup of the last ice age 15 000 years ago to the full establishment of our current interglacial age some 5000 to 8000 years ago) are typically ~1°C/1000 years. On the other hand, even the minimum projected human-induced rates of climate change are on the order of 1°C/100 years up to a potentially catastrophic rate of 5°C/100 years—the latter being some 100 times faster than typical sustained globally-averaged rates of climate change to which human civilization evolved, and the current distribution of species and ecosystems emerged. ▶ VERY LIKELY
- MOST FOREST SPECIES "MIGRATE" at rates of at most 1 km/y, and would not be able to "keep up" with temperature changes at a rate of several degrees centigrade per century without human intervention to transplant them (ie, ecological engineering).[4] ▶ VERY LIKELY
- DIFFERENT SPECIES (eg, specific kinds of trees, insects, birds, or mammals) would all respond differently to projected climatic changes. For example, birds can migrate rapidly but the vegetation some birds need for survival habitat would respond only very slowly (over centuries). This implies a possible tearing apart of the structures of communities of plants, insects, and animals (eg, T L Root[20]) at rates that exceed clear historic or geologic metaphors (eg, R W Graham and E C Grimm[6]). ▶ LIKELY
- CURRENT ENGINEERING AND ECONOMIC PRACTICES in terms of building standards, automobiles, power production, or manufacturing are very retarded relative to the energy efficiency of best available technologies or techniques. Many studies[eg,13,15] show that from 10 to 40% reductions in current CO_2 emissions in the United States could result in long-term costs at or below current rates of expenditure for the equivalent energy services if current inefficient practices and infrastructures were replaced by state-of-the-art, proven efficient practices and equipment. ▶ VERY LIKELY

Figure 2.
Although air-pollution levels have recently improved, surgical masks are worn by those troubled by the still-high pollution levels on Honshu Island, in Tokyo, Japan.
DAVID ALLAN HARVEY

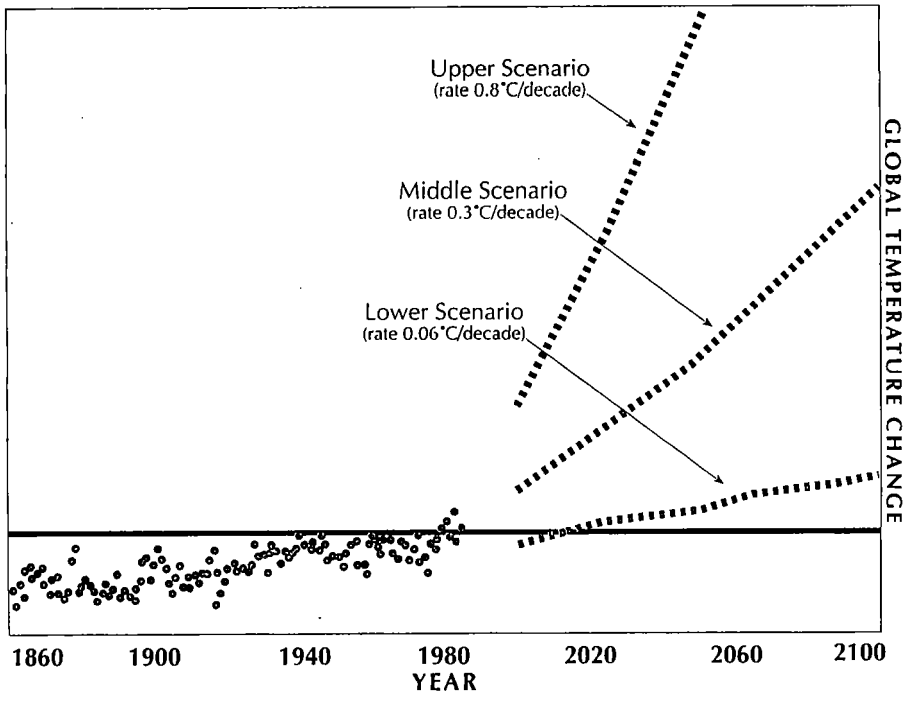


Figure 3.
Three scenarios for global temperature change to 2100 derived from combining uncertainties in future trace greenhouse-gas projections with those of modeling the biotic and climatic response to those projections. Sustained global temperature changes beyond 2°C (3.6° F) would be unprecedented during the era of human civilization. The middle to upper range represents climatic changes at a 10 to 100 times faster pace than long-term natural average rates of change.[9]

The uncertainties in temperature projections over the next century range over a factor of 10 (Figure 3). Including together, uncertainty from human behavioral activities that create greenhouse-gas emissions, biological factors that influence the carbon cycle, and physical factors such as the "feedback effects" of clouds or ice, leads to the differences seen on Figure 3.[9]

Figure 4.
Terraced rice fields on the island of Bali are common. Taking advantage of the run-off from nearby mountains, these fields produce as many as 3 crops a year with centuries-old irrigation systems.
CHARLES O'REAR

Figure 5. (opposite page)
Chisso Company, Minamata, Japan, 1971.
JAMES L STANFIELD

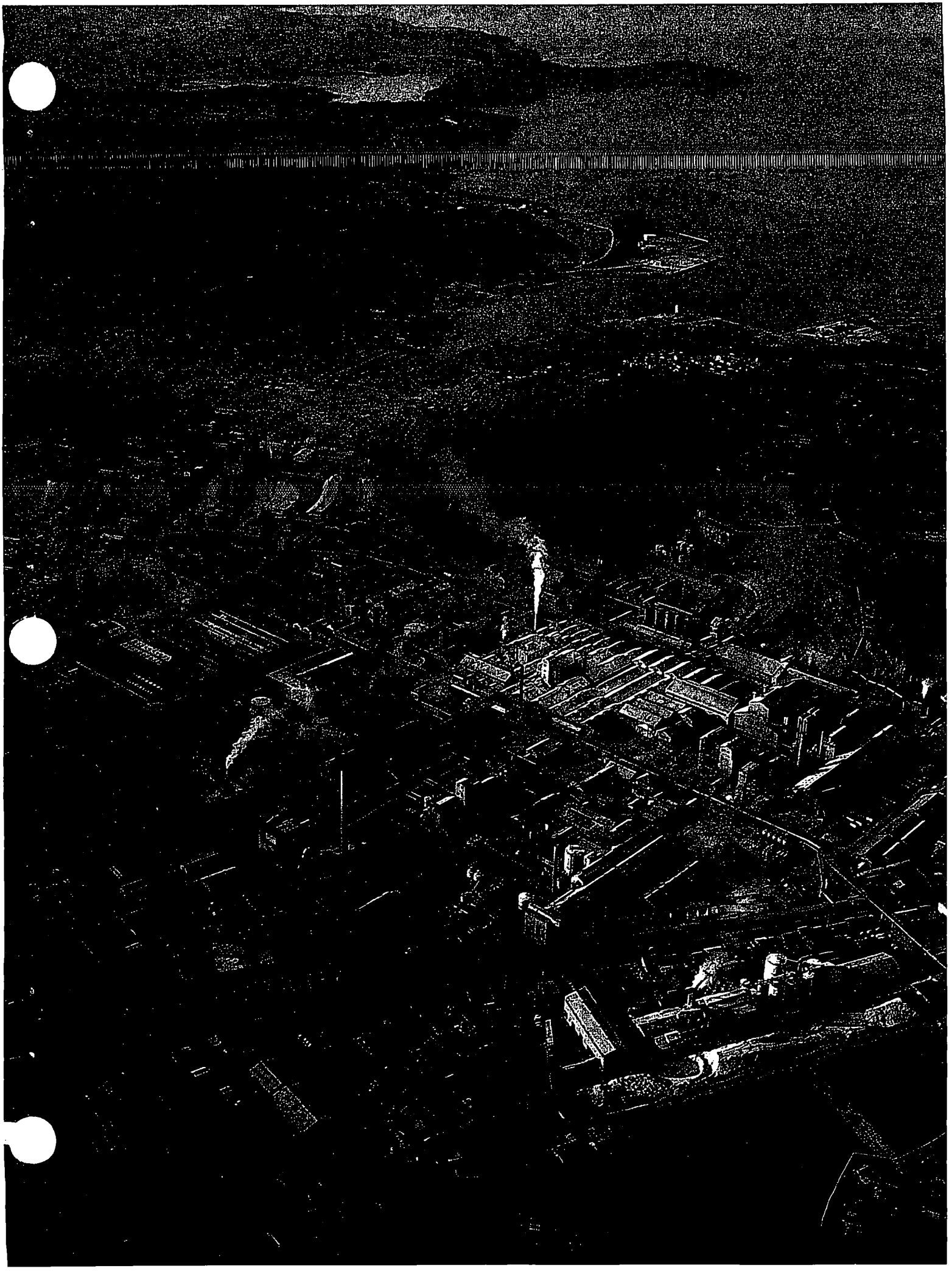
What Is Known with Some Reliability?

A major criticism of global warming has been the imperfect match between the erratic warming of the Earth and the relatively smooth increase in greenhouse gases over the past 100 years. It has been alleged that the temperature trends in the 20th century cannot be attributed to greenhouse-gas buildup, because most of the warming in the 20th century took place between 1915 and the 1940s, followed by a cooling at the very time the global greenhouse gases began to build up rapidly. Then, from the mid-1970s to 1992 there has been a dramatic warming, with the past 12 years of surface temperature containing over a half dozen of the warmest years on record.

Unfortunately, we cannot rule out some possible role for other potential climatic influences or "forcings" as they are called. Among these forcings are: sunspot activity or atmospheric particles from volcanic eruptions, industry, automobiles, and agriculture (Figures 1,2,4,5). It has long been known that most of these particles, for example, tend to cool the planet, counteracting any greenhouse effect, at least regionally.

Very recently, R J Charlson and colleagues[1] picked up on this old debate[cg,2,21,24] of the cooling potential of human emissions of SO_2 (largely from burning sulfur-contaminated oil or coal) and added some quantitative insights. They concluded that sulfuric acid aerosol particles (a form of smog) could both directly and indirectly (by brightening clouds) reflect enough sunlight away so as to nearly compensate for the extra human-caused greenhouse-effect surface-layer heating from CO_2, CH_4, and CFC over most of the Northern Hemisphere landmasses since the 1960s. Since this reflection of sunlight is a daytime phenomenon but the addition of greenhouse gases is a day and night effect, scientists (see, for example R A Kerr[10]) recently have begun to project that the SO_2 effect combined with the anticipated global warming from greenhouse-gas emissions would, at least over land in the Northern Hemisphere, result in a nighttime warming trend. Recently, T R Karl and colleagues[11] noted that over the United States, the former Soviet Union, and China (precisely those places most affected by SO_2 emissions), recent (ie, within the past 30 years) warming trends were indeed largely at night. While 30 years is too little time to allow any confident conclusions, these latest results add (not subtract as some critics have contended) to the confidence that greenhouse-gas buildup equivalent to a doubling of CO_2 would eventually warm the Earth by some 1.5 to 4.5°C. This is all noted in the recent update of the Intergovernmental Panel on Climate Change report.[8]

Finally, for 2 reasons we should take little comfort from the possibility that sulfuric acid particles will "save us" from global warming. First, such chemicals are principal ingredients of acid rain (Figures 19 & 20) and health-threatening smog. Second, aerosols are, as many have noted for decades[cg,23,24] a regional phenomenon, whereas "greenhouse" heat-trapping effects are spread fairly uniformly over the globe. Thus, even if on a hemispheric average sulfur aerosols were to exactly reject as much extra solar heat to space as greenhouse gases trapped heat in the infrared wavelengths near the surface, this situation would not be a cancellation of climatic effects, since the cooling would be in very patterned half-continent-sized intense patches, whereas the heating would be relatively more evenly distributed around the hemisphere. The likely result would be a distortion of normal heating patterns, such as the land–ocean thermal contrast. Such distortions would likely lead to regional climatic anomalies (ie,



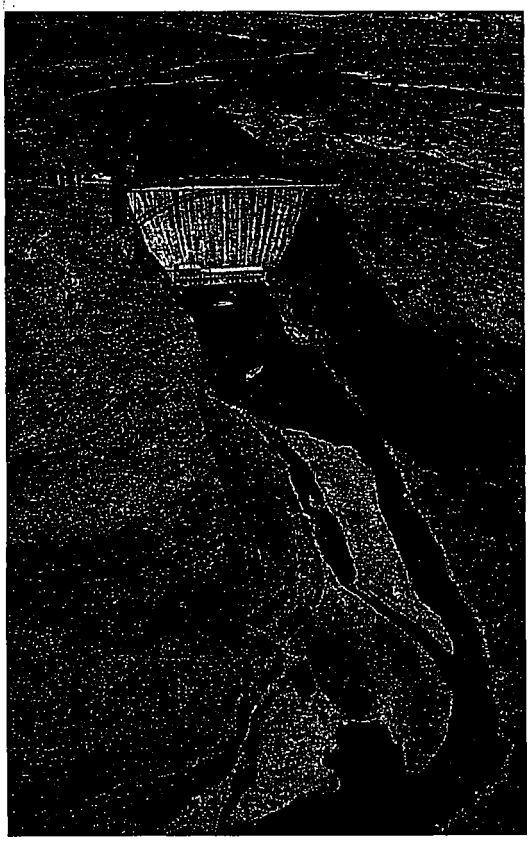


Figure 6.
Drought affects this Colorado River site at Lake Powell and Glen Canyon Dam, near Page, Arizona.
KERBY SMITH

Table 1. **The Sensitivity and Adaptability of Human Activities and Nature**

Human Activity and Nature	Low Sensitivity	Sensitive; adaptation at some cost	Sensitive Adaptation Problematic
Industry and energy			
Health			
Farming			
Managed forests and grasslands			
Water resources			
Tourism and recreation			
Settlement and coastal structures			
Human migration			
Political tranquility			
Natural landscapes			
Marine ecosystems			

NOTE: Sensitivity can be defined as the degree of change in the subject for each "unit" of change in climate. The impact (sensitivity times climate change) will thus be positive or negative depending on the direction of climate change. Many things can change sensitivity, including intentional adaptations and natural and social surprises, and so classifications might shift over time. For the gradual changes assumed in the National Academy of Sciences study, the panel believes these classifications are justified for the United States and similar nations.
SOURCE: National Academy Sciences.[13]

unanticipated local or regional climatic events) even if the net hemispheric temperature changes were small as a result of the hemispheric-scale heating–cooling compensations. In short, we cannot "cure" global warming with SO_2 emissions and escape risk free.

An updated interim report of the Intergovernmental Panel on Climate Change acknowledged these uncertainties, while concluding once again that the 1.5 to 4.5°C warming range is quite likely to cover what the actual long-term temperature response to CO_2 doubling will be over the next 50 years or so.

But most scientists still agree that without 10 to 20 more years of thermometer, satellite, solar, atmospheric pollution, and volcanic observations it is difficult to pin anything down to 99% certainty.

Fortunately, we are now measuring energy output of the sun, eruptions of volcanoes, and pollution-generating activities, and can thus account better for their individual effects. Finally, in short, we are watching some of the other forcings. Thus, as greenhouse gases continue to build up in the future, if greenhouse warming does not take place at roughly the predicted rate during the 1990s and into the next century, then it will be possible to argue on the basis of some direct evidence that the effect predicted by current models is off base. Personally, I will be surprised if our current global "best guesses" prove to be off by >50%.

Indeed, speculative theory is not the principal reason that advocates of concern over the prospect of global warming—and I am unabashedly one of them—take their time and stand before groups such as Congressional committees and take their time with our concern. Rather, our concern is based on the validation exercises for models that we have built of the present and past climate, since these models can also be used to foreshadow the future. In fact, many aspects of these models have already been validated to a considerable degree, although not to the full satisfaction of any responsible scientist.

For example, we know from observations of nature that the last ice age, which was ~5°C colder on a global average than the present era, had CO_2 levels ~25% less than over thousands of years before the Industrial Revolution. CH_4, another very potent greenhouse gas, also was lower by about half relative to preindustrial levels.

Ice in Antarctica contains gas bubbles that are records of the atmospheric composition going back over 160 000 years. Cores drilled into the ice sheets show us that the previous interglacial warm age, some 120 000 to 130 000 years ago, had temperatures and CO_2 and CH_4 levels comparable to those in the present interglacial period.

The well-correlated change in these greenhouse gases and in planetary temperature over geological epochs is an empirical way to estimate the sensitivity of climate to greenhouse-gas concentration changes. Such studies find geological-scale temperature changes from greenhouse-gas variations roughly of the magnitude that one would expect based on projections from today's generation of computer models.[7] However, we still cannot assert that this greenhouse-gas–geological-temperature coincidence is proof that our models are quantitatively correct, since other factors were operating during the ice age–interglacial cycles. The best we can say is that the evidence is strong but circumstantial.

One related point to the ice age–interglacial cycles may be useful here. It typically takes tens of thousands of years to build up ice age glaciers,

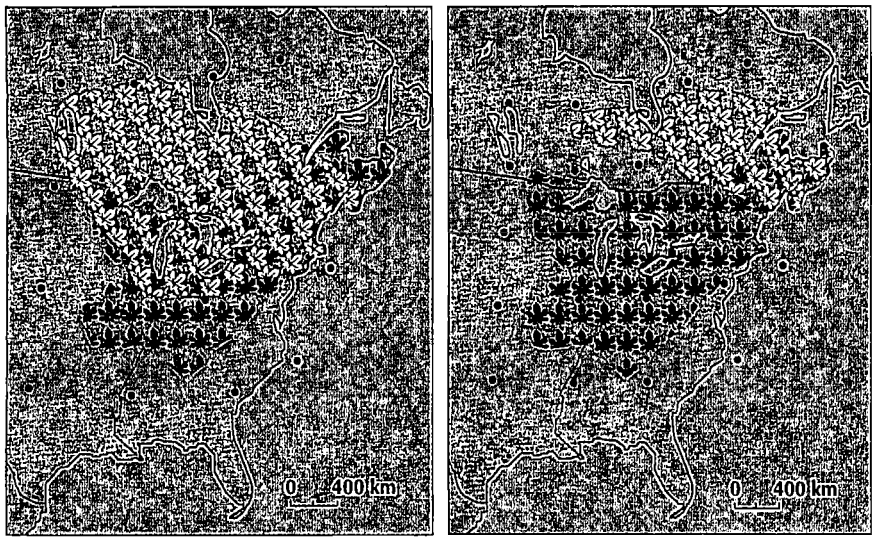


Figure 7.
Present geographical range of sugar maple (red leaves) and potentially suitable range under doubled CO_2 (yellow leaves). A. predictions use climate scenarios derived from the Goddard Institute for Space Studies general circulation model; B. predictions use climate scenarios derived from the Geophysical Fluid Dynamics Laboratory model. Gridpoints are sites of climatic data output for each model. [5]

but only ~10 000 years to deglaciate; and each warm interglacial epoch also lasts typically 10 000 years. Since our current interglacial is now ~10 000 years old, some have suggested that global warming is a good thing because it will hold back the next ice age. What this view ignores is that the time frame for natural interglacial to glacial transitions is tens of thousands of years, whereas the potential for global warming is 2 to 10°C warming in only a century or 2—a radical rate of climatic change relative to most sustained, natural global climate changes in geological history.

What Is Highly Speculative?

Any prediction of what climatologists call the detailed time-evolving, regional distribution of climatic anomalies is highly speculative. It is still tough to be confident in projecting where and when it will be wetter and drier—how many floods might occur in the spring in California, or forest fires in Wyoming or Siberia in August—although some plausible scenarios can be given (pp 180&181; Figures 18&21) . How much sea level will change is also speculative,[eg,22] with most estimates ranging from 0 to 1-m rise by 2100.

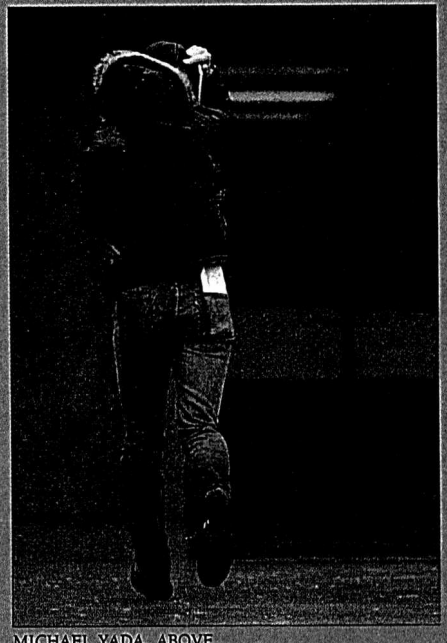
ECOLOGICAL IMPACTS: THE POTENTIALLY MOST SERIOUS CONSEQUENCE

Projecting the time required for regional climatic changes to evolve is still speculative, and so too is any confident assessment of the agricultural, hydrological, ecological, or health consequences of global warming. However, we can construct a variety of plausible specific scenarios of climatic changes over space and time and then ask: "So what?"[eg,16,25] Indeed, such exercises have led to conflicting assessments of the agricultural consequences (Table 1),[eg,13] but greater concern for the hydrological consequences[eg,26] and very serious concern for the ecological implication of most global warming scenarios (Figure 6).[17]

Figure 7 shows distribution of sugar maple trees (Figure 8) under 2 different estimates of climatic changes. The authors of this study noted that their estimates of changes in the ranges of this species did not account for the time it might take for the trees to migrate or the obstacles they might encounter in migration (eg, farms, cities, freeways, acid precipitation, air

Figure 8.
Sugar maple trees, near Algonquin Provincial Park, Ontario, Canada.
DAVID S BOYER

U S DEPARTMENT OF COMMERCE NATIONAL SEVERE STORMS LABORATORY



MICHAEL YADA, ABOVE
ROBERT W MADDEN, RIGHT

STEPHEN M DOWELL, ABOVE; HERRAL LONG, BELOW.

The growing record of climate anomalies in recent years has climatologists speculating that a pattern of detailed, time-evolved regional distribution of extreme weather is developing.

Examples of these recent anomalies are: violent tornados such as this one over East Roosevelt, Oklahoma (opposite page, above); torrential downpours like this one caused by a hurricane in Texas (opposite page, lower left; devastating hurricanes as illustrated by the ruins and remains on Dauphin Island, Alabama (opposite page, lower right); the notorious fire in Yellowstone National Park, Wyoming (above); and heavy snowstorms that leave cars mired in snow drifts in Perryburg, Ohio (left).

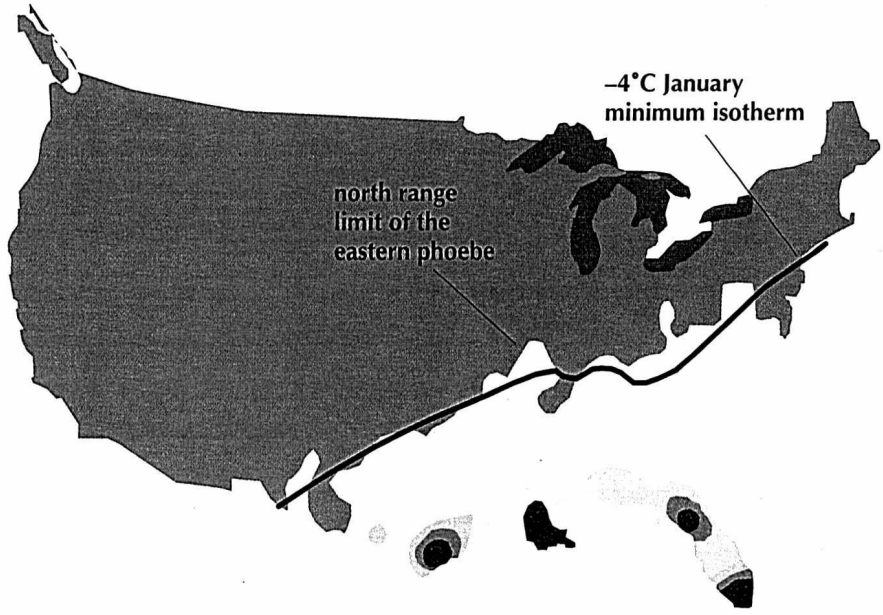


Figure 9.
The distribution and abundance of the winter range of the eastern phoebe. The northern boundary of this bird in winter lies very close to the –4°C isotherm of January minimum temperature (heavy solid line).

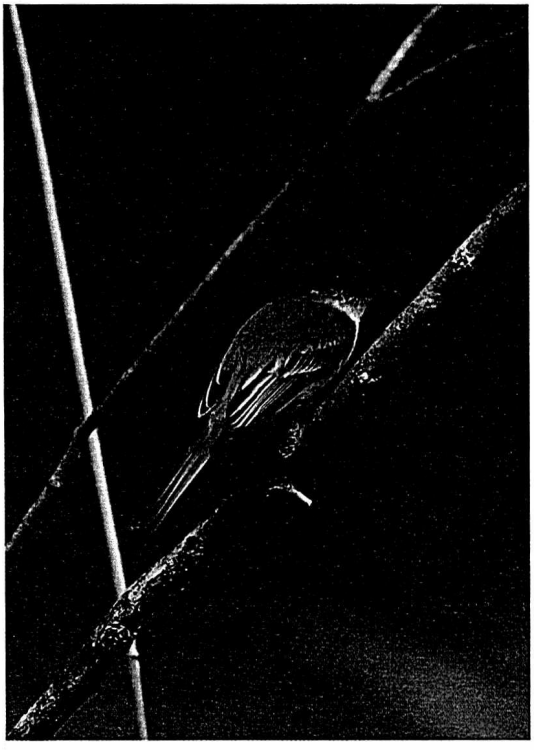


Figure 10.
An eastern phoebe (Sayornis phoebe) *perches on a branch in Everglades National Park, Florida.*
BATES LITTLEHALES

pollutants). Indeed, as University of Minnesota ecologist Margaret Davis[4] noted:

> *The fossil record shows that most forest trees were able to disperse rapidly enough to keep up with most of the climatic changes that took place in recent millennia. These changes were much more gradual than the climatic changes projected for the future. Even so, there were occasional periods of disequilibrium between plant distributions or abundances, soils, and climate that lasted a century or more. The most rapid dispersal rates known from the fossil record, however, are an order of magnitude too slow to keep up with the temperature rise expected in the coming century.*

University of Michigan ecologist Terry Root, additionally, shows the difference for a species of bird (the eastern phoebe, Figure 10) whose winter northern range limit has a close association with mean minimum January temperature; but this winged animal could migrate very rapidly in response to climatic changes (Figure 9). On the other hand, Root, who studied the associations among >100 birds and environmental factors, such as temperature or vegetation, discovered that many species of birds associate with both temperature and vegetation (Figure 11).[18,19] She further noted[20] that birds that are physiologically constrained by low temperatures alone could migrate north when it warms, but those that are also restricted by habitat (eg, vegetation patterns) may have to wait centuries for their required vegetation to migrate before they could shift. In the interim, then, what is likely to occur is a "tearing apart" of the structure of ecological communities, alteration of predator–prey interactions and the potential for "ecological chaos" during the few centuries it will take for climate to warm from a few to 10°C and for the various individual species to respond. Such disruption to "natural balances" would likely enhance extinction, especially for the many species that have limited habitat ranges and are strongly associated with climatic variables.[eg,12]

It is already a formidable scientific challenge to try to explain the range limits and abundance of most species today, even though they have had thousands of years of stable climate to adapt to. Therefore, to predict the highly transient response of biological communities faced with sustained global climatic changes at 10 to 100 times faster rates than natural average

rates of climatic change over the past 15 000 years is speculative at best! However, we do have some knowledge, as previously indicated, of what factors can affect individual species and roughly how rapidly they can respond to various disturbances. Therefore, qualitative statements such as "disruptions of ecosystems," "tearing apart of communities of species," or even "ecological chaos" are plausible "forecasts" should global warming materialize at typically projected rates of 1 to 5°C over the next 100 years.

Other aspects of the global warming issue that are highly speculative are the overall social or economic consequences of typical warming scenarios or the costs of actions to mitigate CO_2, CH_4, N_2O, or CFC emissions or whether to use technological schemes to offset warming (ie, so-called geoengineering).[13]

Although climatic models are far from fully verified for future simulations, the seasonal and paleoclimatic (dealing with remote ages) validation exercises modelers perform are strong evidence that state-of-the-art climatic models already have considerable forecasting skill. And, uncertainties are as likely to render current "best guesses" underestimates as overestimates.

An awareness of just what simulation models are and what they can and cannot do is probably the best we can ask of the public, journalists, and political leaders. Then the tough policy problem is how to apply society's values in choosing to deal with the future given the wide range of possible outcomes that climatic models project.

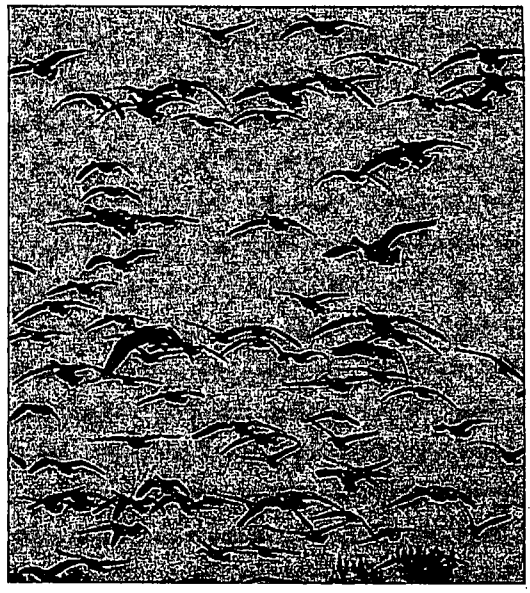


Figure 11.
Gaddy's Wild Goose Refuge, Ansonville, North Carolina.
FREDERICK KENT TRUSLOW

Is It Too Expensive to Act Now?

The final, and perhaps most important, criticism against those proposing action to slow global warming is that the immediate policy steps to decrease CO_2 emissions are too expensive. For example, some newspaper ads by greenhouse critics suggest that if CO_2 emissions are cut, the United States will be bankrupt and the Third World impoverished.

There is substantial Third World opposition to the prospect that developing countries may not be able to have their own industrial revolutions as the developed countries did in the Victorian period when those then-developing Western countries used unregulated amounts of cheap and dirty coal to foster their industrial growth.

Some now-developing countries, notably India and China, have abundant coal supplies (Figure 1). They would like to repeat Western history and use them as low-cost routes to industrialization. Of course, these countries in the 1990s have between them 2 billion people whereas the entire world did not have 2 billion people in Victorian times. So the magnitude of the global impact of now-developing countries' use of coal—should they use coal to produce even a quarter of the West's current industrial standard of living—would be greater than that of developing Western nations in the past. Needless to say, such arguments are not greeted sympathetically in China or India.

CAN CO_2 EMISSIONS BE CUT 20%?

It is sensible, I believe, to argue that now-developing countries need not repeat the experience of Victorian industrialization with smog-choked cities, acid rain, and inefficient power production, given that modern technology has many better solutions. For example, electrical power-genera-

The media debate over global warming frequently polarizes scientists into the "end of the world" or "nothing bad will happen" factions, even though the scientific community at large views these as the least probable outcomes. This false dichotomy is followed by policy grid lock. We need to self-consciously distinguish what is well-known and accepted, what is a good bet, what is highly speculative—and what is scientific (ie, assessing probabilities of various outcomes) from what is a value judgement (what to do given the probabilities and consequences scientists provide).

Figure 12.
Phusriguda village, Orissa, India. Rice field irrigation.
JAMES P BLAIR

Like most other decisions at personal, corporate, state, national, or international levels we face value choices that trade present and future risks against mitigation-policy costs. The environmental sciences are not entitled to a higher standard of scientific certainty than any other area of decision making with a higher degree of technical uncertainty.

tion efficiency today is near 50%, whereas it was half that at the turn of the century. Unfortunately, developing countries typically respond that high-technology, efficient power production is initially more expensive than the traditional options that are cheaper and more available to them. This dilemma sets up the need for a bargain by which developed countries with technology and capital help to provide those resources to developing countries, which in turn develop their economies with the lowest polluting, most efficient technologies, even if they cost more initially.

There have been international efforts afoot to have each nation on Earth commit itself to try to decrease its CO_2 emissions by, say, 20% by the year 2000. This target reduction had been strongly opposed by the United States, as well as some other countries. The Japanese were initially unhappy since they are already about twice as energy efficient as the United States. They claimed it would cost them much more to cut their CO_2 emissions by 20% than the United States, whose relative inefficiency gives it more opportunity to cut cheaply. Nonetheless, the Japanese have recently endorsed specific CO_2-emission limits in the context of the United Nations Conference on Environment and Development.

Developing countries, being even less energy efficient than the United States could, with modest investment, produce vastly less growth in CO_2 (the principal greenhouse gas) pollution if efficient, modern technologies were used rather than the older, cheaper, and readily available technologies, such as low-efficiency coal burning in China or India. The modern technologies that could be tapped by industrializing nationals range from fluid-bed coal burning, nuclear, hydro, geothermal, natural gas, wind, biomass, solar, and possibly, in the very long term, fusion power. This circumstance sets up the possibility for creative international management that might not only eliminate Third World opposition to global emissions reductions but also get them to compete with each other to be the venue for future emissions limitations funded by developed countries. A developed nation could buy itself out of its 20% cut requirement by funding even larger CO_2 reductions in energy inefficient developing nations.

Critics of emissions reductions cite the supposed annual cost of 20% CO_2 reduction at tens to hundreds of billions of dollars. But they often neglect the benefits of emissions reductions: reduced magnitude of global warming, reduced acid rain, reduced urban air pollution, reduced balance-of-payments deficits, and lower long-term operating costs of manufactured products, enhancing competitiveness. Such critics simply cite the potential initial capital costs of CO_2 controls or carbon taxes, write newspaper stories about how many billions each year or trillions over a century it will cost, and scare people away from anti-pollution action.

Some studies have suggested that carbon taxes to promote switching to less polluting energy systems could cost the United States alone "$800 billion, under optimistic scenarios of available fuel substitutes and increasing energy efficiency, to $3.6 trillion under pessimistic scenarios... to [the year] 2100." This quote from the February 1990 "Economic Report of the President" to Congress was based on the initial results of the first wave of economic model simulations.

Because of the controversy associated with such models, the National Academy of Sciences ran a debate among several economic forecasters and their critics. The result was revealing. First, over 110 years (ie, 1990 to 2100) even a trillion dollars in accumulated CO_2 reduction costs, which

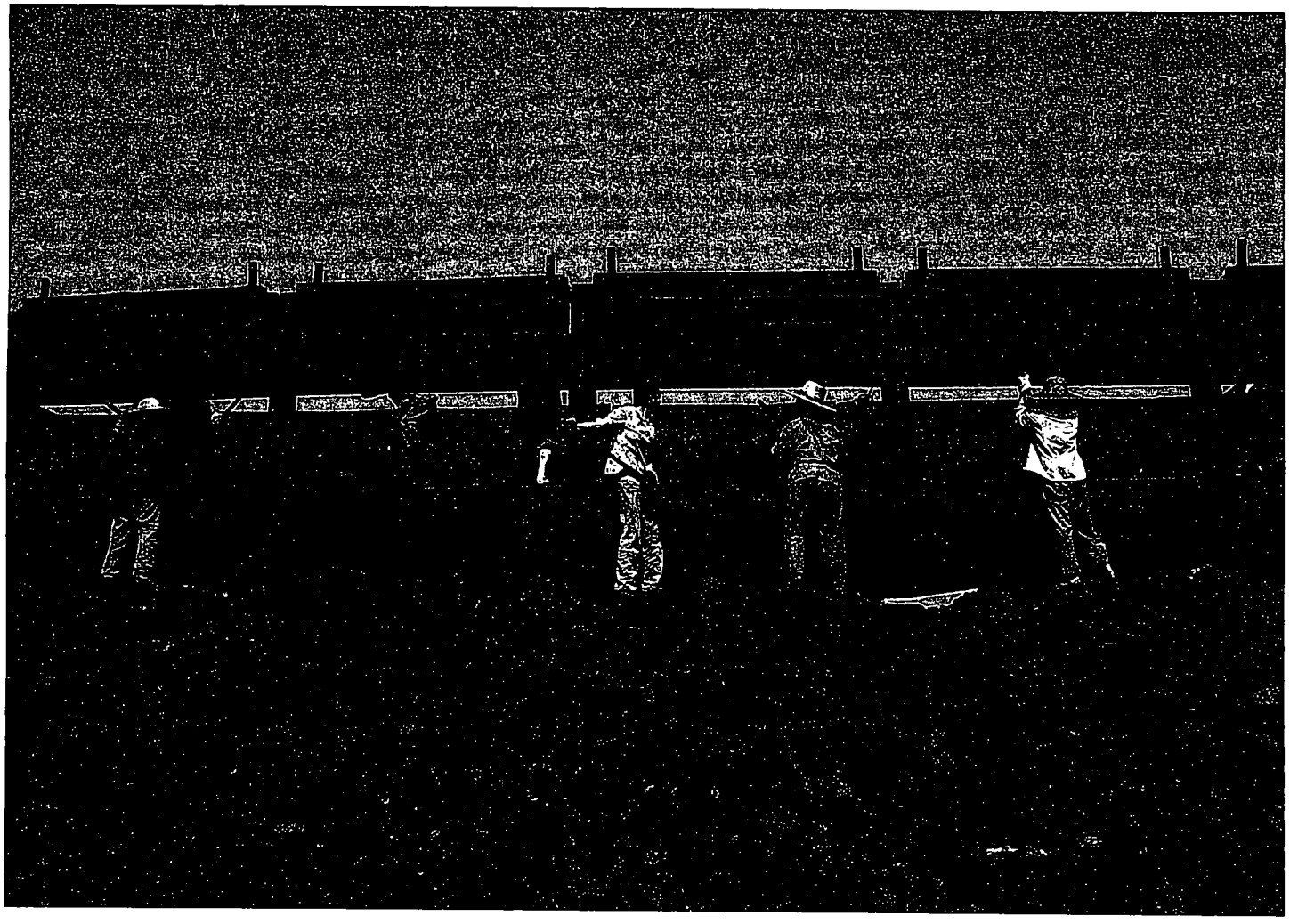


Figure 13.
Leshan, Sichuan province, People's Republic of China. Chinese women stand on top of a mountain of coal as they shovel it into an open-sided train car.
JODI COBB

sounds expensive, is <$10 billion each year—only a few percent of the annual U S defense budget. Moreover, Robert Williams, an energy technology specialist from Princeton University, pointed out that the so-called optimistic scenario of $800 billion in costs to cut U S CO_2 emissions was based on pessimistic assumptions about the rapidly decreasing costs of renewable energy systems like solar, wind, or biomass power.

Furthermore, with the exception of a heroic effort by Yale University economist William Nordhaus, the economists' simulations usually do not even attempt to estimate what direct environmental benefits the United States (or the world) gets for its supposed trillion-dollar investment in CO_2-emission controls. It is unconscionable that some critics of global warming action could cite these already very dubious economic models' cost estimates without so much as a word on the potential benefits of slowing CO_2 emissions. Nordhaus, on the other hand, by balancing costs and benefits in his model runs, argued that cutting annual CO_2 emissions by as little as 10% or as much as 47% would actually produce benefits greater than the costs. However, his model, too, is admittedly crude, laden with unprovable assumptions, and simply cannot by itself provide quantitatively reliable information upon which to base policy choices.

Finally, cross-examination of several economists by National Academy committee members disclosed that their economic models had not even been tested to see how well they performed in predicting the economic

Figure 14.
The carbon tax that would be necessary to raise fossil fuel prices enough in Nordhaus[7] model to achieve the desired policy objective indicated by the color chart to the right.

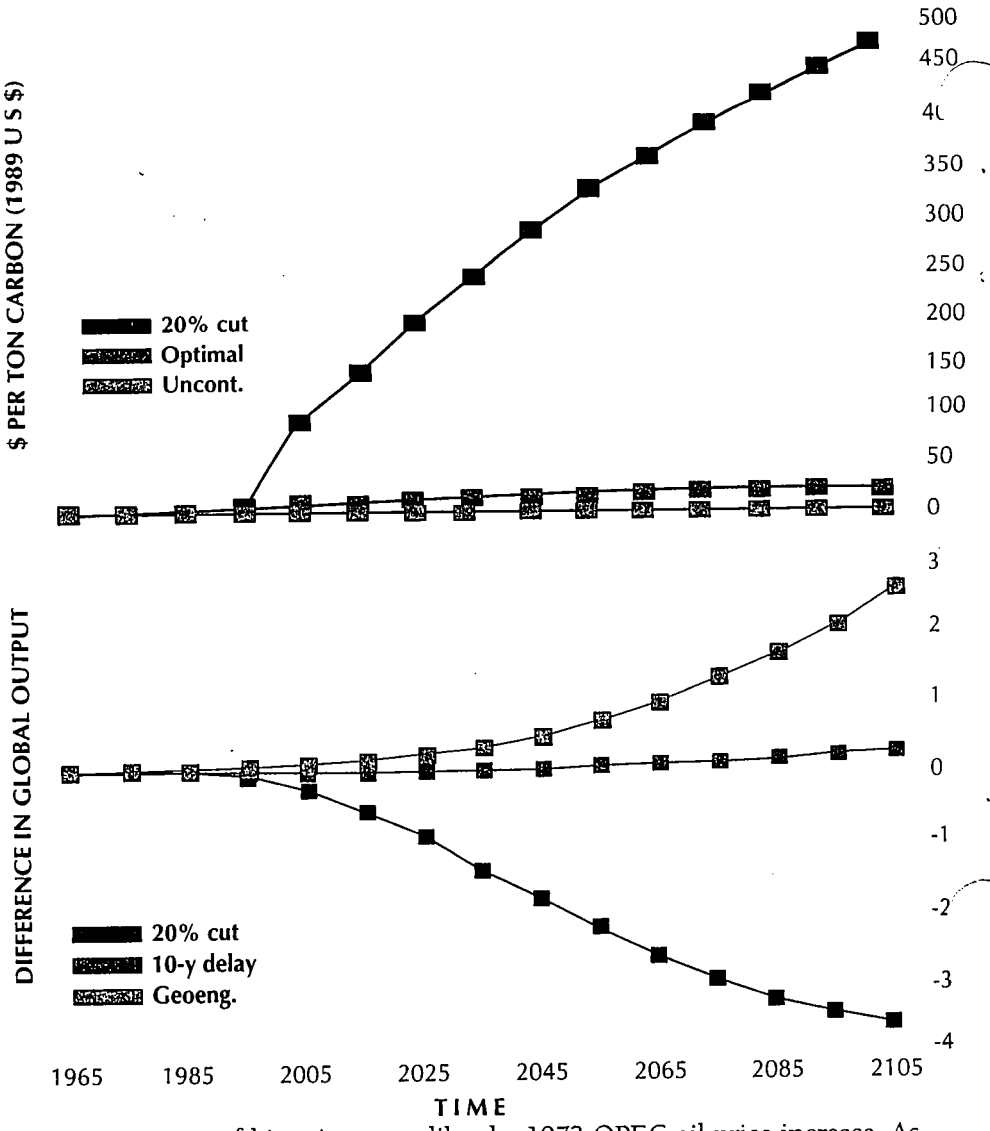


Figure 15.
The impact on Nordhaus[7] economic model of the different policies shown on the figure. Note for perspective that current global output is around $20 trillion per year and in Nordhaus[7] future world gross global output grows to over $100 trillion per year by 2105, with or without CO_2 emissions taxes (see Figure 17).[14]

consequences of historic events like the 1973 OPEC oil price increase. As a participant at that debate, I was concerned that such validation tests were yet to be performed, and dismayed that some global warming critics were actually citing as an alleged rational basis for national policymaking these highly preliminary economic model results for costs of emission controls or taxes without weighing in benefits of such taxes.

Let us pursue the economic modeling issue a bit further. When only the supposed costs to the economy (typically measured as loss of gross national product [GNP] from a hypothetical carbon tax) are shown, seemingly staggering figures emerge (Figure 14). For 1 economic model,[14] the costs run into the trillions by 2105 (Figure 15). The benefit of this "20% cut" Nordhaus calculates (Figure 16) is a 30% reduction in global warming by 2105, only "worth" a percent or less of GNP by Nordhaus' assumptions—since he assumes the primary negative economic consequence of warming to be an agricultural and water supply loss of ≤1% of global GNP (in the United States ~$40 billion per year). He puts no value on the potential for catastrophic effects on ecosystems or the security implications of long-term, very large climatic changes (perhaps ~10°C in the 22nd century as W R Cline noted in his recent economic analysis[3]). Effects such as the tearing apart of communities of species or the impacts on the political stability of South Asia were tropical cyclone intensities to increase are

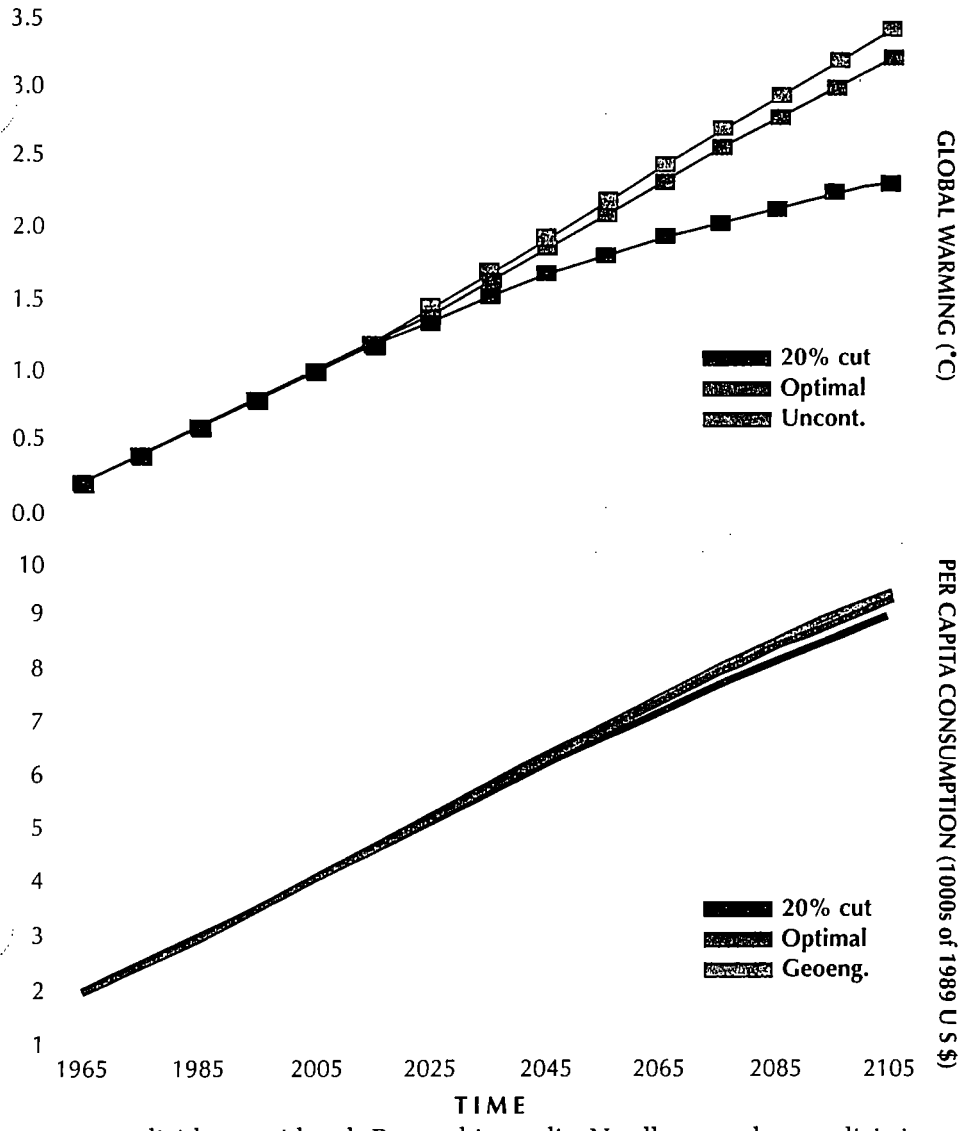


Figure 16.
The projected reduction in global surface temperature increase for the CO_2 emissions scenarios generated by Nordhaus[2] model based on policy alternatives given on Figure 14. [14]

Figure 17.
Projection of real consumption per capita (in thousands of 1989 U S $) for the 3 policy cases on Figure 15. Note that even the so-called draconian 20% CO_2 emissions cut scenario still leads to some 450% growth in this measure of economic well-being, calling into question statements that suggest greenhouse effect controls via carbon taxes would be economically catastrophic. [14] *This figure from the original complete Nordhaus manuscript was omitted from the abridged version published in* Science.

not explicitly considered. But to his credit, Nordhaus makes explicit in Figure 17 (from his original unabridged manuscript[14]) his underlying economic growth assumptions that drive his conclusions. In fact, as Figure 17 shows, there is a >450% growth in per capita consumption from 1965 to 2105 in all his scenarios, and even the "draconian" 20% cut carbon tax scenario still allows 450% growth over this period!

I believe it is shortsighted to risk unabated, unprecedentedly rapid rates of climate change with potentially serious risks to agricultural, hydrological, and (especially) ecological systems of the Earth merely because it will reduce our per capita growth in consumption from some 460% to "only" 470%! It would only take a decade or so more of such growth to achieve "uncontrolled" economic well-being levels in the "20% cut" scenario that so many label draconian. To show Figure 14 with trillions of dollars of potential costs from carbon taxes without also looking at Figure 17 is to have no balanced perspective on the economics and ethics of measures that could mitigate CO_2 emissions. (And even this 20% cut scenario implies major increases in CO_2 emissions associated with traditional growth patterns.)

In any event, while it is possible to use analytic methods and simulation models to investigate costs and benefits of different specific climate-change or emission scenarios, these tools are even less well-validated for

Table 2. Cost Effectiveness Ordering of Geoengineering Mitigation Options

Mitigation Option	Net Implementation Cost	Potential Emission Mitigation ($t CO_2$ equivalent per year)
Low Stratospheric soot	Low	8 - 25 billion
Low stratospheric dust, aircraft delivery	Low	8 - 80 billion
Stratospheric dust (guns or balloon lift)	Low	4 trillion or amount desired
Cloud stimulated by provision of cloud condensation nuclei	Low	4 trillion or amount desired
Stimulation of ocean biomass with iron	Low to Moderate	7 billion or amount desired
Stratospheric bubbles (multiple balloons)	Low to Moderate	4 trillion or amount desired
Space mirrors	Low to Moderate	4 trillion or amount desired
Atmospheric CFC removal	Unknown	Unknown

Note: The feasibility and possible side-effects of these geoengineering options are poorly understood. Their possible effects on the climate system and its chemistry need considerably more study and research. They should not be implemented without careful assessment of their direct and indirect consequences.

Cost-effectiveness estimates are categorized as either savings (for less than 0), low(0 to \$9/t CO_2 equivalent), moderate (\$10 to \$99/t CO_2 equivalent), or high (>\$100/t CO_2 equivalent). Potential emission savings (which in some cases include not only the annual emissions, but also changes in atmospheric stock) for the geoengineering options are also shown. These options do not reduce the flow of emissions into the atmosphere but rather alter the amount of warming resulting from those emissions. Mitigation options are placed in order of cost-effectiveness.

The CO_2-equivalent reductions are determined by calculating the equivalent reduction in radiactive forcing.

Source: National Academy of Sciences, Chapter 11.[13]

Figure 18.
San Cristobal, Dominican Republic. Ruins and remains from a hurricane.
JAMES P BLAIR

long-term studies than climatic models and also do not include many significant factors the authors usually acknowledge. In my opinion, all physical, biological, or economic analytical methods are primarily useful to help a decision maker to obtain a more complete knowledge of the potential benefits or risks of various alternative actions, so as to aid him or her in formulating a heuristic judgment that incorporates what is quantifiable with aspects that are not (eg, the "value" of a species facing extinction). It is a gross misunderstanding of analytical methods, be they climatic, ecological, or economic, to believe they provide the sole bases for arriving at "the answer" on either the effects, consequences, or mitigation policy aspects of global change.

Climatic "Insurance"

The global-warming debate then is both science and politics. But it is essential for the public to understand that there are vastly greater disagreements over what to do about the prospect of global warming (ie, a political value issue) than over the probability (ie, a scientific debate) that unprecedented climate change is being built into the 21st century climate. Estimates of climatic effects range from mildly beneficial (ie, longer growing seasons) to highly catastrophic (ie, more super hurricanes or mass extinctions). These uncertain impacts reflect the wide range of climate futures forecast by most assessment groups, such as those in Figure 3. Although accelerated research will undoubtedly bring more reliable answers sooner, thereby helping to place decision making on a firmer factual basis; I do not believe it likely that any feasible level of research effort

Figure 19.
Lafayette Square, Washington, DC. An acid rain protest sponsored by the U S Public Interest Research Group, Sierra Club, Greenpeace, and the National Clean Air Coalition. The man with the megaphone is Daniel Becker of "Environmental Action."
SARAH LEEN

will pin down the *detailed* environmental or societal consequences of our continuing greenhouse-gas emissions in less than a few decades—the time it will take the climate system itself to answer the question.

Slowing down the buildup rate of the greenhouse gases that threaten unprecedented global warming does not require economically catastrophic measures, nor must it bankrupt industrial nations or doom the poor countries to increasing poverty. Rather, prudent investments in energy-efficient equipment, houses, and power plants combined with sensible reforestation and population-control programs, can both reduce the buildup rate of greenhouse gases and pay their own way. It is ludicrous simply to charge that greenhouse-gas emission cuts are too costly, without weighing the economic, environmental, and strategic benefits of such investments. No individual or business ever got a return without first making an investment. That applies as well to societies and governments—the level at which global-change problems occur and must be addressed.

Every insurance policy has a premium, of course. But these environmental investments not only buy "insurance" against the possibility of unprecedented, possibly dire, climatic change but also can pay large dividends in the form of lowered energy costs, lower balance-of-trade payment deficits, less local air pollution, and lowered acid rain. Therefore, such strategies make sense, even if global warming turns out to be as insignificant as the critics assert. In any case, since mild climatic effects are as probable as catastrophic ones, and since it will take many decades to resolve major uncertainties, we can take the most cost-effective steps now, and then press more or less to mitigate further as new national and international scientific assessments report the latest findings of the scientific community every few years over the next several decades.

But if the warming turns out to be as bad as or worse than most current "best guess" projections, such climate insurance will have been very wise indeed.[cg.3] An insurance policy that pays big dividends on the premium even if the catastrophe never materializes, it seems to me, is the most rational response to the coin-flipping probabilities of unprecedented climate change and attendant ecological disarray that most knowledgeable scientists agree we are facing as we enter the next millennium. None of the noisy polemics of the past few years has changed that basic consensus.

Figure 20.
Statues in a Louisville, Kentucky cemetery illustrate the effects of acid rain, created by the reaction between atmospheric moisture and fossil-fuel emissions. A black crust forms on the Madonna because it is sheltered, while the angel has no buildup because of the scouring but nevertheless corrosive action of the rain.
TED SPIEGEL

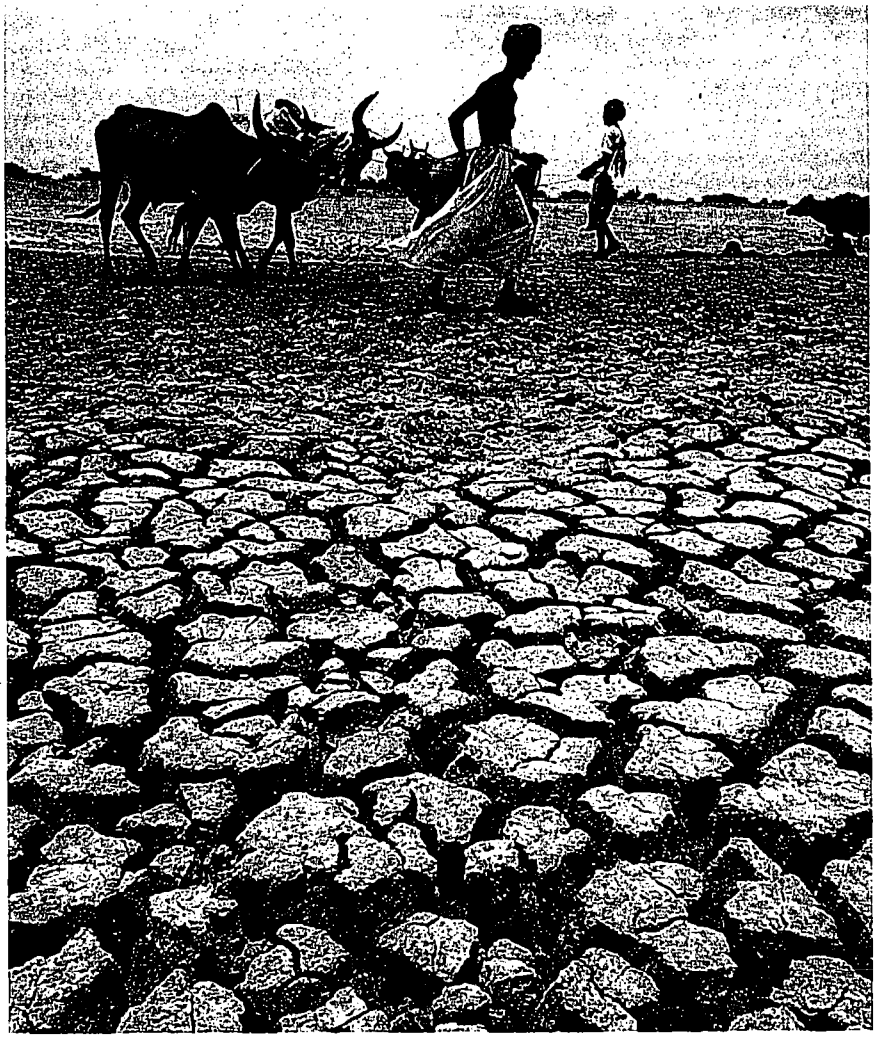


Figure 21.
Herders lead bony cattle to water across cracked patches of mud in Rajasthan, India. After the monsoons, this area will be a lake.
STEVE McCURRY

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Absence of Scientific Basis

RICHARD LINDZEN

Current concerns over significant global warming are based on simple, plausible physical arguments that increasing CO_2 levels will lead to some warming. Model predictions of large warming depend on projected large increases in atmospheric CO_2, and mechanisms within the models which act to greatly amplify the climate response to increasing CO_2. The projections depend on questionable economic, population, and energy scenarios; they also depend on clearly inadequate chemical models which serve to exaggerate the fraction of emitted CO_2 remaining in the atmosphere. The amplification mechanisms (positive feedbacks) depend on what is likely to be a severe misrepresentation of the relevant physical processes: moisturization of the atmosphere and cloud formation. Recent data suggest that these processes may be acting in a manner opposite to what current models produce. Under the circumstances, the possibility of large warming, while not disproven, is also without a meaningful scientific basis.

GIVEN NORMAL CLIMATE VARIABILITY, we may reasonably expect that there will be future climates both warmer and colder than the present regime. This, however, hardly supports the current fear that increasing greenhouse gases in the atmosphere will lead to catastrophic warming. The Intergovernmental Panel on Climate Change (IPCC) Scientific Assessment as well as the current update[11,12] both recognize that temperature changes over the past century (a net warming of 0.45°C ± 0.15°C) are consistent with natural variability and smaller than would be expected for models predicting >~1.3°C equilibrium warming for a doubling of CO_2—assuming all the change over the past century were due to CO_2. This, of course, seems unlikely since the bulk of the warming occurred before 1940. Thus, the data neither suggest nor support current warming scenarios. Neither do simple greenhouse considerations. All other factors remaining constant, the equilibrium greenhouse warming, resulting from a doubling of CO_2, is estimated to be between 0.5°C and 1.2°C.[11,16,18,27]

These values may seem small, but CO_2 is only a minor greenhouse gas. If all CO_2 were removed from the atmosphere, water vapor and clouds would still provide almost all of the present greenhouse effect. Predictions of larger equilibrium warming depend crucially on positive feedbacks from water vapor, cloud cover, and surface albedo (due to snow cover). Of these model feedbacks, water vapor is by far the largest. As it turns out, the physics of the water-vapor budget is largely absent in current models. Indeed, in most (if not all) models the water-vapor feedback is readily identifiable with a calculational error. Thus, there is no theoretical basis for the catastrophic warming scenarios, as well. Indeed, there are reasons to believe the feedbacks are negative, suggesting the equilibrium response to CO_2 doubling may well be much smaller than the direct response.[27,28]

Finally, the term equilibrium should be explained. It refers to the response achieved over an infinite time. In point of fact, the actual response time (largely determined by heat transport into the ocean) increases proportionally to the expected equilibrium response.[9] In fact, a model predicting a 4.8°C equilibrium warming for a doubling of CO_2 would only have reached 2/3 of this warming in ~160 years. It is interesting, in this regard, to note that the models examined in the IPCC Scientific Assessment produce warming by 2100 almost equal to the equilibrium response of these models to a doubling of CO_2; in these models, however, effective CO_2 has quadrupled by 2100. Had it only doubled, the predicted warming would have been much less.

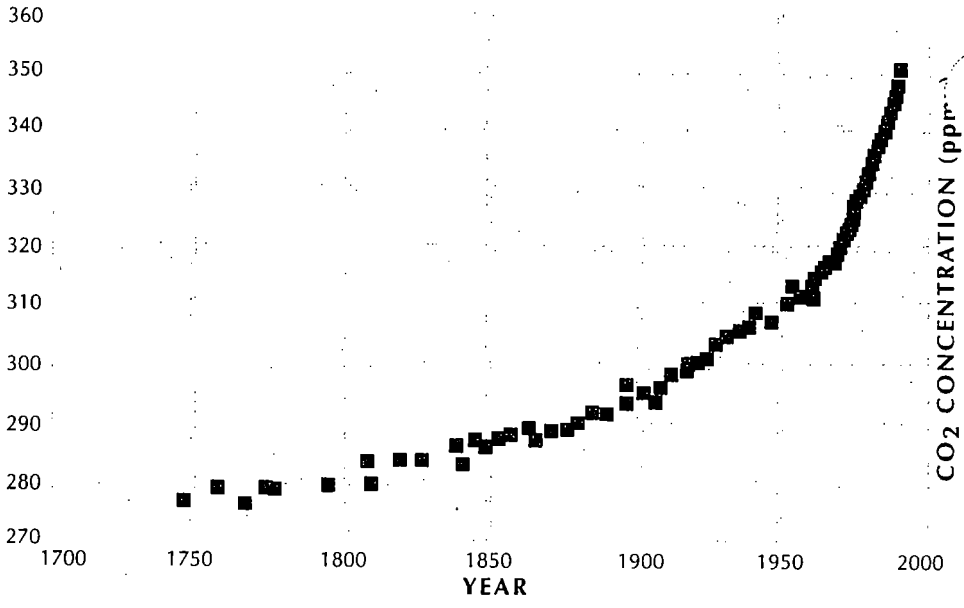

Figure 1.
Atmospheric CO_2 increase in the past 250 years, as indicated by measurements of air trapped in ice from Siple Station, Antarctica (purple) and by direct atmospheric measurements at Mauna Loa, Hawaii (blue).[11]

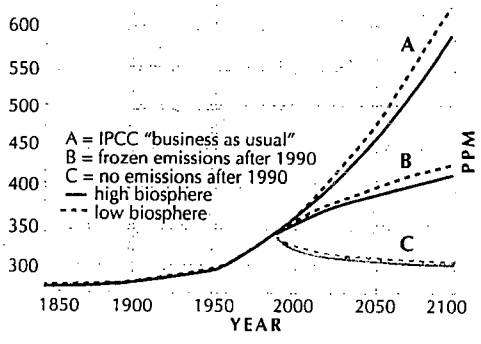

Figure 2.
Expected CO_2 in the atmosphere according to various emissions scenarios.[10]

CO_2 = carbon dioxide
CFC = chlorofluorocarbons
CH_4 = methane

RICHARD S LINDZEN, Alfred P Sloan Professor of Meteorology, Department of Earth Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139.

CO_2

Before even discussing "greenhouse theory," it may be helpful to begin with the issue that is almost always taken as a given: namely, that CO_2 will inevitably increase to values double and even quadruple present values. Before 1958, the record is based on the analysis of ice cores. After 1958, it is based on direct atmospheric sampling. Clearly, CO_2 has been increasing (Figure 1). Before 1800 the density was ~275 ppmv (parts per million by volume). Today it is ~355 ppmv. The increase is generally believed to be due to the combination of increased burning of fossil fuels (Figure 3) and (mostly before 1905) to deforestation. The total source is estimated to have been increasing exponentially with a characteristic time of 45 years—at least until 1973. From 1973 until 1990 the rate of increase has been slower. About half the production of CO_2 has appeared in the atmosphere.

Predicting what will happen to CO_2 over the next century is a rather uncertain matter. By assuming a shift toward coal, advances in the 3rd World's standard of living, large population increases, and a reduction in nuclear and other non-fossil fuels, one can generate an emissions scenario that will lead to a doubling of CO_2 by 2030—if we use a particular model for the chemical response to CO_2 emissions. This was referred to as the "business-as-usual" scenario by the IPCC Working Group I. As it turns out, the chemical model used was inconsistent with the past century's record; it would have predicted that we would already have ~380 ppmv. An improved model developed at the Max Planck Gesellschaft in Hamburg shows that the so-called business-as-usual scenario does not even double CO_2 by the year 2100.[10] Their model shows that under other scenarios, we may not even get much more CO_2 than is already in the atmosphere (Figure 2). Personally speaking, it seems unlikely that the indefinite future of energy belongs to coal. I also find it difficult to believe that technology will not lead to improved nuclear reactors within 50 years. As the IPCC update notes, scenarios are not predictions. Given our present "crystal ball" technology, predictions for 50 to 100 years are more than anyone would rationally attempt.

Nevertheless, we have already seen a significant increase in CO_2 which

Congressional / Legislation Testimony

News From U.S. Senator **Robert C. Byrd** West Virginia
Phone (202) 224-3904

For Immediate Release
Thursday, June 19, 1997

Contact: Ann Adler
(202)224-3904

Statement of Senator Robert C. Byrd
Before the Subcommittee on International Economic Policy,
Export and Trade Promotion
Senate Committee on Foreign Relations
June 19, 1997

Mr. Chairman, I thank you for the opportunity to appear before the subcommittee to discuss the critically important issue of the negotiations aimed at signing a protocol during the third session of the Conference of the Parties to the United Nations (UN) Framework Convention on Climate Change, which is scheduled to be held in December in Kyoto, Japan. I am concerned that the protocol that results from these negotiations could have a serious impact on American industry and on our economy, while at the same time failing to address a looming threat to the global environment.

On June 12, I introduced a Sense of the Senate Resolution, together with Senator Hagel and a bipartisan group of my colleagues, which addresses the conditions for U.S. agreement to revisions to the United Nations Framework Convention on Climate Change. The resolution has been cosponsored by 60 Senators from both sides of the aisle. This resolution states the Sense of the Senate that the developing world must fully participate in the treaty negotiations and commitments and play a meaningful role in effectively addressing the problem of global climate change.

In essence, the resolution accepts the thesis, which is still the subject of some dispute, that the increasing release of carbon dioxide (CO_2) and its accumulation in our atmosphere are causing a very gradual heating of the globe, which has many adverse consequences for us all. I believe the Administration should be commended for its efforts on this issue, and I commend this subcommittee for its attention to this matter. If substantial steps are going to be taken to influence carbon dioxide and other greenhouse gas emissions, we need to accelerate new technologies, anticipate new developments, and encourage public/private sector participation.

President Bush signed the United Nations Framework Convention on Climate Change, the so-called Rio Pact, in 1992, which was subsequently approved by the Senate, and calls on the

industrialized nations to aim to reduce their greenhouse gas (GHG) emissions to their 1990 levels by the year 2000, a goal which will not be achieved by the U.S. nor by the vast majority of the industrialized nations unless further steps are taken.

The parties to the Framework Convention met in Berlin in 1995 to discuss the future direction of the treaty in light of this projected failure to meet the voluntary objectives, agreeing that any new commitments would be binding upon the signatories. Specifically excluded from any new commitments, however, would be the countries that comprise the developing world. The rationale for the so-called Berlin Mandate was that it is the industrialized OECD (Organization for Economic Cooperation and Development) nations that have been the major emitters of greenhouse gases in the past, and will continue to be in the next decade.

There are two intrinsic problems with the Berlin Mandate. First, while the industrialized world is the primary contributor to the current problem, that will not be the case in only a few years. *[REFER TO CHART ONE]* As this chart demonstrates, the emissions of the developing world are rapidly increasing on a sharp, upward slope. These emissions will actually surpass those of the industrialized OECD nations by the year 2015. In short, the developing world is rapidly becoming a clone of the OECD nations.

Let us assume that the current negotiations for a new protocol, which are to be concluded in Kyoto this December, result in a binding commitment that the OECD nations must reduce their emissions to 1990 levels by 2010. *[REFER TO CHART TWO]* This chart demonstrates that under such a scenario the OECD nations will sharply reduce our emissions of greenhouse gases. The price we will pay in order to achieve these reductions is open to debate, as estimates differ. Nonetheless, the key point is that this responsibility will not be shared because of the Berlin Mandate, for the chart clearly shows that the emissions of the developing world continue on their inexorable upward track, even as we in the OECD group make the painful and costly adjustments necessary to force down our emissions.

This demonstrates the second problem with the Berlin Mandate, which is that we gave away the store, and we received nothing in return. Many of the biggest emitters of greenhouse gases in the developing world have refused to even discuss, let alone seriously consider, taking any emissions limitations commitments upon themselves. In what can only be viewed as an act of environmental irresponsibility, the developing nations have adamantly refused to recognize that they will, over the next two decades, become the primary cause of the problem, in terms of annual emissions.

The refusal of the developing world to discuss any future

emissions limitations commitments has become a central issue, for any attempt to bring them into the process is labeled by some as a "treaty killer." I have a different perspective. My resolution is not a treaty killer. It is, in fact, a treaty enhancer. It calls upon the Administration not to agree to a protocol, unless it includes new commitments to limit or reduce greenhouse gases emissions for developing country parties within the same compliance period. My resolution improves the treaty. For any treaty that does not include emissions limitations provisions for the developing world is inherently unsound and ineffectual on its face. Environmentally, we are all in the same global boat. What good does it do for the United States and other developed nations to work feverishly to plug the holes in the boat, if the developing nations are drilling holes at the other end just as fast as we plug them? Be assured that the global boat will sink just as rapidly and we are all going to be in for a long, long swim.

Bringing the developing world in under the climate change tent, as part of any future treaty, will not only increase the prospects of Senate ratification, it will also be enormously beneficial for the international environment. Let me further clarify that point. *[REFER TO CHART THREE]* This chart shows the world of 1995, in terms of world carbon emissions in millions of metric tons of carbon. The United States and OECD nations, shown in red, are responsible for a little over half of that total. *[REFER TO CHART FOUR]* The next chart projects the world as it might be after the currently proposed treaty is adopted, with only the developed world taking action to reduce greenhouse gas emissions. The difference is startling. The developing world, shown in purple, has assumed the U.S. and OECD nations' place as the biggest global polluters. The problem remains the same, only the names have changed. And again, because of the flawed Berlin Mandate, all of these emissions from the developing world will be completely uncontrolled, and free to increase even further. From this perspective, it is the Berlin Mandate -- and the fact that it lets the developing world off the hook scott-free -- that will seriously harm the global environment in future years.

[REFER TO CHART FIVE] Finally, let us examine the role of China. Despite possessing a strong and growing economic and industrial base, despite possessing the ability to launch satellites into orbit, China is still counted among the family of developing nations. But its industrial growth is matched by its growing contribution to global pollution. This chart compares China's contribution to global carbon emissions to the contribution made by the United States. On the left, we can see that based upon current trends, China will surpass the United States in carbon emissions by 2015. On the right, we can see that if current proposals are adopted, under which we would reduce our carbon emissions to 1990 levels, while imposing no requirements upon the developing world and China, China all by itself will <u>greatly</u>

exceed the United States in metric tons of carbon emitted.

I find it disturbing that despite its future role as the world's leading contributor to the problem of carbon emissions, China has indicated steadfast refusal to apply any type of binding obligations upon its own economy and industries. I believe that if the treaty we are negotiating today does not equally commit developing nations like China to binding commitments, there will be no incentive for China and the other nations of the developing world to make responsible and environmentally sound choices as they develop. You can be sure that after China assumes its role as a leading carbon emitter, she will not be very eager to make the tough and costly corrections to retrofit her industries to reduce emissions of greenhouse gases. Indeed, she may expect to benefit from a treaty in which she escapes binding commitments, because it may allow her to import industries from OECD nations what would chose to relocate there rather than change their ways and clean up their acts at home.

My message to U.S. negotiators is that all nations, but particularly those that are making and will make a significant contribution to greenhouse gas emissions, need to (1) make commitments at Kyoto that unequivocally demonstrate an action program to tackle this problem, and (2) to start with aggressive efforts to act on those commitments immediately and not settle for vague promises to return to a future negotiation to get serious. Finally, while countries have different levels of development, each must make unique and binding contributions of a pace and kind consistent with their industrialization. The developing world must agree in Kyoto to some manner of binding targets and commitments which would begin at the same time as the developed world in as aggressive and effective a schedule as possible given the gravity of the problem and the need for a fair sharing of the burden.

In closing, I note that my resolution states than any treaty presented to the Senate be accompanied by a "detailed explanation of any legislation or regulatory actions that may be required to implement the protocol or other agreement and should also be accompanied by an analysis of the detailed financial costs and other impacts on the economy of the United States which would be incurred by the implementation of the agreement." There surely will be costs if the United States is to make the changes to our existing industrial base and to our existing lifestyle necessary to meet the goals of this treaty. Our smokestacks must be cleaner and our automobiles more efficient. There are many ways to achieve these goals. We must be able to tell the American people what will be required to meet any proposed commitment.

Politically, I believe that there needs to be a strong consensus between the President and Congress about any plan of action. The Administration's policy of follow-on multilateral

negotiations to deepen the impact of the Rio Pact requires very substantial consensus-building with the Congress, and broad educational activities to bring the American public along. To impose effective, legally-binding measures on the U.S. economy, will mean having the strong support of the Senate. We Senators need to be deeply concerned over the alarm that has been expressed to us by a very broad range of American industry and labor over the impacts on our economy of a treaty which commits the United States to deep emission reductions, and which does not spread the burden of responsibility equitably across the globe. These assessments by bedrock American industry must be taken seriously. I hope that this hearing will result in new Senate attention to the progress of these negotiations, and that this Committee will serve to interact regularly with the State Department and Administration policy-makers as our negotiating strategy is developed and refined.

The resolution that Senator Hagel and I introduced, and which has won the support of a majority of sixty Senators, is aimed at that negotiation, and beyond. Since carbon and other greenhouse gases can accumulate in the atmosphere and persist for long periods, we will not as a community of nations get a handle on these threats to our global climate unless everyone participates and does their share to solve the problem. We all share our earth in common. We breath the same air, and we are exposed to the same global climate system. We must all accept our share of the responsibility for the global climate. We must keep this fragile boat afloat, together, and the sooner we have commitments from all its passengers to work together in that effort, the better.

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Congressional Hearings Testimony

Statement of

Kevin J. Fay
Executive Director
International Climate Change Partnership

before the

Senate Foreign Relations Subcommittee
on International Economic Policy, Export and Trade Promotion

June 19, 1997

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Statement
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Kevin J. Fay
Executive Director
International Climate Change Partnership

before the

Senate Committee on Foreign Relations
Subcommittee on International Economic Policy,
Export and Trade Promotion

June 19, 1997

Good Morning, Mr. Chairman and members of the Committee. My name is Kevin Fay; and I serve as the Executive Director of the International Climate Change Partnership (ICCP), a coalition of U.S. industry representatives and associations, as well as international associations, interested in the policy development process with respect to global climate change. We appreciate the opportunity to appear before the Subcommittee today on the subject of a global climate change convention.

ICCP was organized in 1991 to provide a forum to address the issue of global climate change and to be a constructive participant in the policy debate. Six months before the Third Conference of Parties meeting in Kyoto, the issue has certainly raised the interest of many of us in the private sector and the Congress.

ICCP continues to recognize the climate change issue as an important matter with which governments should be concerned. However, it is a very long-term issue and extraordinarily complex in both its underlying science and its entanglement with the very foundations of the global economic structure.

We have just recently communicated our views on the key issues in the Kyoto negotiations to the Administration. I am attaching this correspondence to my testimony and ask that it be included in the record. We have also communicated to the President on the issue of the Administration's as yet unreleased economic analysis, expressing our frustration at their

lack of communication on the matters of greatest concern to the private sector--namely the potential economic impacts of a climate change agreement and the current thinking of future implementation scenarios. This letter is also attached.

Our views have been based on the premise that the only agreement that is acceptable is one that is comprehensive and can work with flexibility, maintain national sovereignty, ensure participation by all countries, maintain a competitive level playing field, and is guided by effective science and includes a long-term objective that will guide future policymakers and future negotiators.

You will note that in both letters, we urge the President and the State Department to use the opportunities of the upcoming G-8 meeting and the United Nations General Assembly special session on the environment to reiterate to our negotiating partners that the U.S. policy framework enunciated last July is the only framework that can provide a climate change agreement that is both environmentally beneficial and economically feasible.

Since prior to the first meeting of the parties in Berlin, we have consistently argued that the time is not yet right for a climate change agreement. Unfortunately, the parties established an artificial deadline under the Berlin mandate to reach an agreement at COP-3, now scheduled to be held in December of this year.

In our view the Administration made progress in its own deliberations and offered a thoughtful policy framework at COP-2 which we have heard about here today. This policy outline includes a comprehensive approach; identification of a long-term objective; identification of a developing country role under the treaty; implementation flexibility through emissions trading, banking, and joint implementation; and avoidance of a laundry list of so-called "policies & measures."

The U.S. framework also included a call for a binding commitment, which the Administration has subsequently defined as an emissions budget period of undetermined length to achieve reductions of an undetermined size. While most of the attention has been focused on this part of the discussions, we continue to believe that it is not the only key to a successful treaty agreement in Kyoto or beyond Kyoto.

We should point out at this time, however, that we have been provided with no analysis to justify any particular target or timetable that might be advocated.

Our primary concern has been that the result of the negotiations would focus on only one or two of the key issues, some of which we have outlined in our letter, and that the rest would be left until later. This would be unacceptable to us. This worst result would be for the Administration to agree to some target and not achieve the entire policy framework it has advocated.

We have heard testimony today on the Byrd-Hagel Resolution, and we commend the Senators for raising the important issue of requiring an agreement that includes developing country commitments. We believe very strongly in this principle. We have concerns, however, that just as some have focused only on identifying a target or timetable as an acceptable Kyoto outcome, others may focus on only one or another of the remainder of these key issues we have identified.

An agreement on a target and timetable in Kyoto, and nothing else, would be unacceptable to the ICCP. An agreement in Kyoto on a target and timetable, including a developing country schedule, but with none of the flexibility or other provisions as articulated last year by the Administration, would be just as unacceptable.

To date, we have been disappointed in the progress on most of these fronts and we are pessimistic on the ability to achieve them between now and Kyoto absent strong signals by the White House to reinvigorate the negotiations. ICCP is not and never has been interested in an agreement at the Kyoto meeting just for the sake of reaching an agreement. This view will not change.

With respect to the economic issues and the impacts of a climate change agreement on the U.S. economy, jobs, and the environment we remain very concerned. It is difficult to address this issue in any effective way given the lack of dialogue on these topics and the lack of information being provided by the Administration. We know that the economic analysis that has been performed tells us several important things:

--that there are costs involved in reducing greenhouse gas emissions;

--the costs are likely to be reduced if flexibility provisions are incorporated;

--that you cannot achieve any reasonable goals either environmentally or economically without developing country participation; and

--the costs are less if you avoid premature capital retirement or turnover, and provide industry the opportunity to manage their way into the technological innovation that will be necessary to accomplish whatever long-term goal is established by the parties to the convention.

It is difficult to know how the costs compare to the benefits because we have yet to see any analysis that includes the benefits of mitigating climate change or facilitating adaptation strategies.

In order for there to be an effective treaty, we believe that the parties must first get the treaty structure correct. We have a long way to go before that will happen.

Our companies have determined that the current state of scientific understanding requires a prudent long-term approach to address this issue. This view is equally applicable to the negotiations themselves.

We appreciate the opportunity to appear before you today, and we look forward to answering your questions.

INTERNATIONAL CLIMATE CHANGE PARTNERSHIP

June 6, 1997.

President William Clinton
The White House
Washington, D.C. 20500

Dear Mr. President:

On behalf of the International Climate Change Partnership, I am writing to express our concern for the status of the economic analysis for purposes of the international negotiations on climate change and the apparent lack of progress in making the economic issues an integral part of these negotiations. The ICCP is a coalition of companies and industries around the world committed to responsible participation in the climate change policy process.

ICCP continues to recognize the climate change issue as an important issue with which governments should be concerned. However, it is a very long-term issue and extraordinarily complex in both its underlying science and in its entanglement with the very foundations of the global economic structure. ICCP commended the U.S. position enunciated in its statement in July of last year as a reasonable framework, and was particularly supportive of its efforts to give the negotiations greater focus on the long-term character of the issue and its economic implications.

It is disturbing to us that, for nearly one year, there has been little public discussion of the economic impacts of the range of proposed climate change mitigation strategies by any of the parties, including the United States.

The Administration had promised the results of its economic analysis to the Congress, its negotiating partners, the private sector and the non-governmental organizations. While we applaud the recognition of the need to peer review this work, the slow pace at which this activity is occurring raises concerns that it is either not being seriously pursued, or that the results are not being shared. Neither of these reasons, if true, bodes well for constructive private sector support of the Administration's efforts or for any result produced from the Third Conference of Parties meeting to be held later this year in Kyoto.

This matter is further complicated by the recent resignation of Under Secretary of Commerce Ehrlich, who was coordinating the analytical effort. His departure suggests a possible further loss of momentum on this important effort at a critical time.

Those who may be able to provide constructive input into the analysis and assessment being pursued by the Administration wonder what must be done to understand how specific industry sectors are being examined and what steps are being contemplated in order to pursue your climate protection goals. At a minimum, the Administration should be able to immediately publish the policy assumptions being used for individual sectors.

In addition, aside from frequent references to implementation of flexible, market-based approaches, there has been little discussion of what may be suggested as implementation steps for a Kyoto agreement. Failure to discuss some of these issues in advance will likely make it difficult

to build support for ratification of the international agreement and for development of implementing legislation.

We respectfully urge you the Administration to provide an outline of the economic information and policy considerations, as well as a meaningful timeframe for the release of this information.

Finally, we understand that you are preparing to attend the meetings of the G-7 and the United Nations General Assembly Special Session on the Environment. We urge you to reiterate the United States' support for these key economic issues as critical elements of any future agreement on climate change. It is only with these key policy provisions that we will have a climate change agreement that is both environmentally beneficial and economically feasible.

Sincerely,

Kevin J. Fay
Executive Director

INTERNATIONAL CLIMATE CHANGE PARTNERSHIP

June 6, 1997

The Honorable Timothy Wirth
Under Secretary of State for Global Affairs
Department of State
Washington, DC. 20520

Dear Mr. Wirth:

You have requested our views on specific issues under consideration as part of the negotiations on implementation of the Berlin Mandate for a possible protocol or other legal instrument to the Framework Convention on Climate Change. We are pleased to provide these comments on specific issues of concern to the members of the International Climate Change Partnership (ICCP) with respect to the treaty negotiations. We are also writing, however, to express our concern with the current lack of focus to the negotiations or linkage of these issues with the important relationship between the international treaty and domestic implementation schemes.

ICCP continues to recognize the climate change issue as an important matter with which governments should be concerned. However, it is a very long-term issue and extraordinarily complex in both its underlying science and its inextricable entanglement with the very foundations of the global economic structure. We are concerned that this complexity is exposing an overly ambitious timeframe for current negotiations and that the cohesive activity necessary to ensure a viable foundation for future action under this important treaty simply has not come to be. It is equally disturbing that there has been little public discussion of the economic impacts of the range of climate change mitigation by any of the parties, including the United States.

ICCP commended the U.S. position enunciated in its statement in July of last year as a reasonable framework, and was particularly supportive of its efforts to force into the negotiations greater focus on the long-term character of the issue and its economic implications. However, we have made clear that our support is for the entire framework, and not for individual components. Some have misconstrued this position as support for early targets and timetables. It would be incorrect to read our position as such. While ICCP members have recognized the possibility that negotiators would agree on a mid-term emissions target, we could not specifically support such a target given the current lack of understanding of the implications of such a target or how it would be implemented.

In our view, the issue of a binding target is not the most critical element of the negotiation. We view it more important to provide definition to the treaty structure through a long-term objective and a mechanism to ensure that all parties, developed and developing, have clearly defined roles before we enter into a binding commitment period. It is also important that the parties are able to achieve these goals with flexibility through emissions trading, banking, and true joint implementation. We appreciate that the U.S. has recognized this need for flexibility.

It is of great concern to us that little progress appears to have been made on many of these issues concerning flexibility and the role of developing countries. While the U.S. has elaborated its views on these positions in subsequent statements and its protocol draft, we have detected little movement by the other parties on these issues. Since we are not privy to your bi-lateral discussions or the behind the scenes meetings, it is difficult for us to determine the current status of these topics.

It is not acceptable to us for the negotiations to conclude in December with an agreement on a binding commitment towards a mid-term target with all details on other key provisions to be negotiated later.

As you recall, we have consistently expressed our view that 1997 is too soon for a credible technical assessment process which would support an agreement by the parties on these issues. The apparent lack of progress to date, the dearth of information available to us regarding how these issues may be resolved, and the failure to thoroughly discuss the economic implications for an agreement, have only served to confirm this view.

We have pledged to work responsibly with the United States and other parties on the development of an effective framework to address the climate change issue consistent with the need for all nations to sustain economic growth. We remain committed to this principle. It is not clear, however, that these issues can be resolved satisfactorily by the Kyoto meeting. ICCP will, of course, reserve any judgment on the results of Kyoto for the implementation process.

We urge the United States to remain focused on and committed to delivering concrete results on all the points outlined in the statement delivered last July and elaborated on in its subsequent submittals. Further, we believe that the U.S. should indicate its commitment to its proposed climate change policy structure at the upcoming meetings of the G-7 and the United Nations General Assembly Special Session on the Environment.

Concurrently, we believe the economic impacts of a possible agreement should be communicated with industry and other policymakers so we can have an effective dialogue. Failure to discuss some of these issues in advance will make it extremely difficult to build support for ratification and implementation of the international agreement.

We look forward to working with you and appreciate the opportunity to discuss the specific views on the attached position paper in the very near future.

Sincerely,

Kevin J. Fay
Executive Director

Enclosure

cc: The Honorable Madeleine Albright
Secretary, Department of State

The Honorable William Daley
Secretary, Department of Commerce

The Honorable Federico Pena
Secretary, Department of Energy

The Honorable Rodney Slater
Secretary, Department of Transportation

The Honorable Carol Browner
Administrator, Environmental Protection Agency

The Honorable Frank Murkowski
The Honorable Dale Bumpers
The Honorable John Chafee
The Honorable Max Baucus
The Honorable Thomas Bliley
The Honorable John Dingell
The Honorable Dan Shaefer
The Honorable Ralph Hall

International Climate Change Partnership
Views on
Key Issues in the Climate Change Protocol Negotiations
(In Alphabetical Order)

Developing Country Role

The United States has outlined a specific proposal for dealing with the developing country role as part of the Kyoto agreement, including definition of obligations under Article 4.1 of the Framework Convention, establishment of an Annex B of countries which would voluntarily adopt emissions budgets, and a date certain by which all parties would have emissions budgets.

As stated by Bert Bolin, Chairman of the Intergovernmental Panel on Climate Change (IPCC) at the March 1997 meeting of the Subsidiary Body on Science and Technological Advice (SBSTA) in Bonn, "[I]t is obvious from this graph that no reasonable future reductions by Annex I countries would stabilize global emissions." Therefore, it is imperative that developing countries be part of this agreement. Furthermore, as stated in the Administration's recent economic work, a significant percentage of infrastructure and industry investment by developed countries is occurring in developing countries. Finally, because of the strong linkages between population growth and greenhouse gas emissions, it is important that we recognize that seven of the current non-Annex I countries represent two-thirds of the world's population.

The Administration has been forthright in its insistence that the developing country role be defined. ICCP recognizes the potential limits of the current Berlin Mandate with respect to new commitments for non-Annex I Parties. It is clear, however, that the Berlin Mandate contemplates definition and elaboration of Article 4.1 commitments for all Parties, including the developing countries.

Additionally, it is imperative that additional developing country participation, including emission budgets, must be defined prior to the start of the first binding budget period for the current Annex I parties. It is only through such definition that governments and the private sector can ensure that investment flows are not distorted.

Entry into Force

ICCP has noted that six countries, including India and China, currently account for 55% of greenhouse gas emissions. In order for the treaty to enter into force, it is imperative that a significant percentage of greenhouse gas emissions be represented by ratifying countries. In addition, a significant percentage of Annex I countries and developing countries should ratify the treaty before it enters into force.

We also believe that it is inappropriate for a regional economic organization to be allowed to represent both itself and the voting rights of its individual members. The EU has argued that it should be allowed to bubble its emissions and is proposing to allocate emissions internally. It is unfair that the EU be granted this concession to bubble its emissions when it declines to support similar flexibility for other Parties. Therefore, the EU should have to decide to either bubble and count as one vote, or to not bubble and to be counted individually.

Greenhouse Gas Comprehensive Approach

The protocol negotiations should continue to focus on a comprehensive approach at the international level. Recent proposals from the European Union suggested a protocol on only three gases--carbon dioxide, methane, and nitrous oxide--with the notation that fluorocarbon compounds should be covered by policies and measures and added to the basket in the year 2000. ICCP strongly opposes the EU approach. The gases that can be measured should be covered simultaneously in a comprehensive manner. The key to a comprehensive approach is for Parties to focus on achieving the most efficient emission reductions possible; and therefore, it is unproductive to segregate gases from coverage until a later date or to treat gases differently in an international agreement

Long-Term Objective

ICCP has urged the negotiators to provide for a long-term focus or objective. We believe such an objective provides clarity to negotiators, as well as to those charged with implementation of commitments. It is our understanding that the United States has performed some analysis of this issue, and that such analysis could be useful to the negotiators currently. Furthermore, we applaud the article in the U.S. protocol proposals which contemplates a long-term objective.

This objective will be an important guide to future decision making, including private sector investment planning. We note that several participants, including the EU, and certain environmental organizations have suggested certain objectives characterized as atmospheric concentrations of greenhouse gases, and that the IPCC documents present their analysis according to atmospheric loading of greenhouse gases measured in parts per million (ppm) of CO2 equivalent.

ICCP has not advocated a greenhouse gas concentration as the appropriate measure for the long term objective. A long-term objective could be defined as a combination of adaptation, impacts, and concentration measures.

Recent analysis of the economics of climate change controls have indicated that the long-term objective is not as relevant as the path charted for the emission reduction. In our view, it is impossible to develop a meaningful path without knowing the point of departure and the intended goal.

We recognize that the current state of science does not provide a precise "correct" answer. Science does provide a basis for making an informed political judgment on the objective, and scientific assessment through the IPCC and elsewhere is critical to future reassessment of any potential long-term objective.

Policies and Measures

It is imperative that each nation maintains maximum national flexibility with respect to implementation of its climate commitments. It is neither appropriate nor productive for the negotiators to determine the manner in which each country should achieve its commitments. ICCP is opposed to any listing of specific annexes of policies and measures in any manner, i.e., mandatory, regional coordination, voluntary, or exemplary.

Target/Budget/Accountability Period

There have been several proposals for specific point targets and/or budget periods as part of the protocol proposals that are currently before the Parties. ICCP has not endorsed the notion of a binding "target." We do, however, recognize that all of the government proposals to be considered in Kyoto do contemplate such a step as a starting point.

The lesson from the non-binding commitment of the 1992 FCCC agreement is that, despite the best of intentions, a specific point target is very difficult to administer due to fluctuations in economic conditions, weather conditions, etc. Therefore, we believe it is imperative that the long-term objectives be utilized to examine a reasonable path that minimizes short-term economic disruption and stimulates the longer-term technological innovation necessary to significantly reduce worldwide greenhouse gas emissions.

The U.S. has indicated a preference for an emissions budget period and a binding commitment to achieve that budget. In our view, the practical timetable for ratification and implementation of a Kyoto climate agreement, including subsequent definition of a developing country role, suggests that meaningful program implementation steps could not be up and running with confidence any time soon after a Kyoto agreement. There has been a great deal of focus on the beginning of such a so-called budget period.

In our view, the beginning of the budget period is not as important as the end of the budget period, i.e., the point at which the principle of "binding commitment" actually has the potential to impose penalty or sanction. In light of the uncertainties stated above, ratification, implementation, developing country role, and some level of experience with the implementation process, we believe that it would be inappropriate to end the first binding budget period before the year 2020. This time frame will allow industry to develop its programs, and gain confidence in their performance.

ICCP also believes this time frame is consistent with its previous position that policies at the outset of this effort must take into account a reasonable period for capital stock turnover. This will provide a period for industry to "ramp up" its climate change responses.

If the budget period is to be adopted, we believe that it should be long enough to encompass weather and economic cycles, but not so long as to present an impossible horizon to provide both industry and policymakers with some certainty. Therefore, it appears that a 10-year budget period is better than a 3 or 5-year period.

Technology Assessment

Although not specifically included as part of the current protocol proposals, ICCP continues to believe that the FCCC must be grounded in sound scientific and technological assessment processes. This function, as currently served primarily through the Intergovernmental Panel on Climate Change (IPCC), is inadequate.

The IPCC is currently considering restructuring proposals including the adoption of working group outlines that incorporate an effective role for private sector expert participation. We encourage support for these proposals.

Finally, it is also important that we de-politicize the IPCC process to the maximum extent possible. Its credibility can be sustained only if it is truly seen to be the work of scientific

and technical experts, and not subject to the whims of the diplomatic and political process or other special interests.

Trading, Banking and Joint Implementation (JI)

Most available economic analysis continues to indicate that flexibility through emissions trading, banking of emission credits, and joint implementation policies can help to maximize greenhouse gas emission reductions most cost-effectively. ICCP is fully supportive of such mechanisms as part of any agreement in Kyoto and beyond.

We believe it to be imperative that such principles be included in the first agreement and not be left to some future negotiations. We also believe it is important that these provision not be relegated to some pilot project with final decisions to be made at some future date.

Finally, it appears that flexibility is a positive inducement to ensure maximum compliance. It also would allow us to avoid the use of trade restrictions or trade sanctions as an enforcement mechanism in the treaty.

~~Hearings~~
Congressional
~~Legislative~~
~~Hearings~~
Testimony

Testimony of Timothy E. Wirth

Under Secretary for Global Affairs

Department of State

Before the Subcommittee on International Economic Policy, Export and Trade Promotion of the Senate Committee on Foreign Relations

June 19, 1997

Good morning, Mr. Chairman. I am pleased to join you this morning to discuss the importance of climate change and to outline the United States negotiating position as we move toward December's multi-national conference in Kyoto.

Climate change is probably the most important environmental challenge facing the world. The ecological, human, economic and political consequences are of enormous importance for the mid-term and for the long-term – and each of us needs to understand them. We look forward to active and frequent consultations with this Committee and with the other members of Congress as we seek to reach an agreement and as we set up the needed long-term process.

The Science

I want to begin with the science – because scientists were the ones who drew our attention to climate change in the first place, and because we continue to base our policies on the best evidence and the most rigorous scientific analysis available.

Let me highlight some of the key scientific issues on which there is a global consensus:

- human activities have significantly increased the atmospheric concentrations of greenhouse gases over the last century.

- global average temperatures have already increased by about one half to one degree Fahrenheit.

- the balance of evidence suggests a discernible human influence on global climate.

- projections of the future change, based on complex climate models and on our best understanding of the physics of the climate system, suggest an increase of another 2 to 6 ½ degrees Fahrenheit by 2100, with an average greater than any seen in the last 10,000 years.

- Sea levels are projected to rise an additional 1 ½ feet by 2100, from expansion of the oceans due to global warming, and from a melting of glaciers and ice sheets.

- Climate change is likely to have wide-ranging and mostly adverse effects on human health, with direct and indirect effects leading to increased mortality.

- Coastal populations and infrastructure are vulnerable: a 20 inch rise in sea levels would put about 100 million people at risk each year from storm surges, with significant costs.

- Natural and managed ecosystems are at risk as ideal ranges shift with the climate. The location of forest and agricultural zones will change significantly.

- Future unexpected changes in the climate are not included in the models. These surprises may have impacts of global magnitude such as fundamental changes in global ocean circulation or ecosystem behavior.

These are the conclusions of the Intergovernmental Panel on Climate Change -- an international body of more than 2500 scientists, expert in all aspects of climate change, including the physical sciences, the social sciences and the economics. U.S. government experts have endorsed their work, as have the academic communities in the United States and around the world.

An excellent summary of the science and the impacts that could occur as a result of global climatic disruption was presented yesterday on behalf of nearly 2500 leading American scientists and I would like to include their statement for the record.

We do not yet have all the answers with respect to the science. We cannot yet say with certainty what the local effects of climate change will be. But, with better scientific data, the picture is becoming clearer.

For instance, in the United States, twenty inches of sea level rise would inundate 9,000 square miles of U.S. coastal land, with great loss of property and infrastructure. Rising temperatures could double the number of heat-related deaths. We now know that the ten warmest years since records began all occurred since 1980. Some of the most recent data shows that four of the five hottest years have occurred since 1990. With CO2 concentrations doubled in the atmosphere, heat waves like the one that killed around 500 people in Chicago two summers ago would be four to six times as likely to occur.

While we acknowledge uncertainties about where, how fast and when climate change will occur, and while we continue to press for research that will help us to answer these important questions, the basic fact remains that we are having a discernible impact on our climate.

Our policy is based on the current scientific consensus and on the need to achieve the most cost-effective emissions reductions possible. Our policy has three simple and straightforward objectives which are outlined in detail in a framework proposal we submitted to the climate convention in January. The proposal was shared with this Committee and was distributed widely with the public. The three objectives are as follows:

1. We are seeking to establish a legally binding emissions target for developed countries which is verifiable, credible and realistic.

2. We are seeking an agreement in Kyoto that maximizes the flexibility for each country to meet this legally binding target, including through the use of market mechanisms.

3. Third, we recognize the importance of involving all countries in the agreement – and to this end we have incorporated extensive language into our proposal that calls for developing countries to act.

Let me go through each of these in greater detail.

The Target: It is clear that the Framework Convention on Climate Change has not proven adequate to the task of reducing global emissions. We anticipate that only two countries will meet the Convention's non-binding aim of lowering emissions to 1990 levels by the year 2000. We ourselves will miss the aim by about 10%.

We believe a binding legal obligation to act will result in the passage of domestic laws – in all countries – that compel action. In order to build in some flexibility, our proposal calls for the targets to be multi-year in nature. Without this sort of legal obligation, countries will continue to pay only lip-service to their efforts to solve this problem. The past shows this is not enough.

Flexibility: Solving the problem of climate change is a long-term proposition that will require enormous effort over a sustained period. It is therefore vital that we achieve emissions reductions as cost-effectively as possible. Our approach to climate change seeks to do this. We have recommended that each country be given the maximum flexibility to meet its legal obligation. And we have rejected common, harmonized policies and measures recommended by some countries. We have also learned from the successes of the past, and are, wherever possible focusing our efforts on the use of market mechanisms to reduce costs.

One of the most innovative of these is the introduction of "emissions trading" into the lexicon of international agreements. The concept has been successfully used to reduce costs (as much as tenfold) in meeting the standards set for power plant emissions of sulfur dioxide. A similar program has also been successfully implemented in the Montreal Protocol on Substances that Deplete the Ozone Layer. In the climate context, we envision that Parties would be allowed to trade their emissions – seeking to reduce them where it is most cost-effective to do so. While we are still engaged in working through some of the details of how to implement this proposal, it is clear that such a program could significantly reduce the costs; some studies suggest by up to one-half.

Another piece of our strategy on flexibility is joint implementation. Through joint implementation, countries are allowed to undertake emissions reductions

projects in developing countries and count these reductions against their own emissions. We believe that joint implementation holds enormous potential to reduce global greenhouse gas emissions in a cost-effective manner. Joint implementation would also produce other benefits such as encouraging technological innovation, promoting the use of cutting-edge U.S. energy technologies, and protecting forests and other critical habitat around the world.

The U.S. has extensive experience with successful joint implementation projects. Recently, our approach on joint implementation received a major boost when President Clinton received the endorsement of the Dominican Republic and the seven Central American nations to endorse our concept of joint implementation for credit. This is a good example of our commitment to pushing through flexible mechanisms to implement new commitments under the Climate Change Protocol.

Developing Countries: We recognize the importance of including developing countries in this agreement. Their participation is critical to achieving any kind of a lasting success in combating the threat of climate change. For that reason, the participation of developing countries has been a central piece of our own negotiating strategy. We must seek a level playing field in which all countries that contribute to the problem contribute to its solution.

Developed countries, including the former Soviet Union and the countries of Eastern Europe, contribute about 60% of global emissions today, and developing countries account for about 40%. What do these numbers tell us? First, that the developed countries have historically contributed the greatest amount to the current heightened concentrations; we have fouled the nest. But the developing countries are rapidly growing, as are their emissions. The United States, with 5% of the world's population, is the largest greenhouse gas emitter, with more than 20% of the world's emissions. But China is not far behind, and is expected to pass us sometime in the first quarter of the 21st Century, although on a per capita basis, its emissions are projected to be less than one fifth of our own even then.

There is a clear concern about the potential impacts on our international competitiveness. Let me assure you that developing countries are part of our negotiating strategy and they must join us in order to insure that no country suffers significant competitive disadvantage.

We are all in this together, with different histories but with the same future. We pull a heavier oar at the beginning; over time, we all must pull together. Our policy has to be calibrated to reflect this reality. We cannot expect to solve the global problem unless all countries -- developed and developing -- participate in the solution. To this end, we have proposed three separate elements for developing countries in our proposal for Kyoto:

1. We call on developing countries to continue to elaborate on their commitments in the Convention – including by providing information on emissions on an annual basis (the same as for developed countries), and by taking "no regrets measures" (actions which may be valuable in their own right, and which also mitigate climate change). We also call for a regular review of the actions developing countries are taking (again, using a review process similar to that established to assess our own actions).

2. We call on the newly developed countries (such as Mexico and Korea) to take on binding legal obligations to reduce emissions, recognizing that while the targets they adopt may not be the same as our own, such commitments will codify their new status, and differentiate them from the lesser developed countries. We are now working with potential members of this group to seek their agreement on such a step. While by no means an easy task, we believe that in Kyoto, we can find some language to insure that countries in this category will take on commitments that correspond to their more developed status.

3. We call for the negotiation of a new legal instrument which will include legally binding obligations for all countries – including all developing countries – as a next step in the path toward the ultimate stabilization of greenhouse gas concentrations in the atmosphere at a level that is not

dangerous. This step, too, faces significant difficulty in the negotiations leading toward Kyoto.

Finally, I want to take this opportunity to note that one of the most important potential incentives with regard to additional developing country participation--the Global Environmental Facility -- would be seriously undermined if Congress does not fully fund the U.S. contribution to this program. I hope you will support our request of $100 million for the GEF for this year.

Let me close this morning by briefly reviewing for you the negotiating process between now and December 1 – when we meet in Kyoto for the third session of the Conference of the Parties to the Convention.

We have two more one-week officials-level negotiating sessions – the first in late July in Bonn, and the second in late October, also in Germany. During these two weeks we will be examining and negotiating the extensive text, which is a compilation of all the material submitted by all countries. This is an extremely divergent and broad document reflecting many interests around the world and it must be moved toward some consensus.

At one end of the spectrum, reflecting their strong commitment to making an aggressive statement, the European Union has proposed that developed countries reduce emissions by 15 % below 1990 levels by the year 2010. The

Organization of Small Island States has proposed a 20% reduction by the year 2005.

At the other end, reflecting their concerns with the potential impacts of various emission reduction proposals (particularly on reductions in the consumption of fossil fuel), OPEC countries have introduced a proposal that they be compensated for any economic cost they might incur as a result of treaty requirements.

Other countries have introduced recommendations that they be allocated an individualized, different target. This commitment to so-called "differentiation" is not yet defined, but is used by many countries as a first step toward finding their own way of joining the negotiating process.

As we examine these proposals, and develop our own negotiation strategy, we will continue to be guided by our own principles of feasibility and economic opportunity. We are, as you know, doing extensive economic modeling, and we have not yet completed the process. We expect the modeling will soon be completed and available to all interested parties.

I think it is useful as we think about the economic impacts of reducing greenhouse gas emissions that we remember over 2,300 economists, including eight Nobel Laureates, have endorsed a statement which in part states:

"... As economists, we believe that global climate change carries with it significant environmental, economic, social, and geopolitical risks, and that preventive steps are justified...For the United States in particular, sound economic analysis shows that there are policy options that would slow climate change without harming American living standards, and these measures may in fact improve U.S. productivity in the longer run."

I would ask that the economists' statement also be included in the record.

Finally, I should note that we understand that Kyoto is but one more step on the long road toward stabilizing the atmospheric concentrations of carbon and other greenhouse forcing gases. The long-term goal is stabilization of concentrations of greenhouse gases in the atmosphere at an acceptable level. This is a task that must begin now but which will require a sustained effort over the next decades.

Kyoto is a first step, but a very important one. The message that we send, by what we do, is enormously important. We believe we can succeed by:

-- developing new technologies, and thus improving the way we fuel our economy, transport ourselves, and process materials

-- using flexible economic instruments and market mechanisms

-- bringing in developing countries as full partners

-- fulfilling the obligations of our leadership role

And throughout this process, we can continue to promote economic development and improve the standard of living for the American people, while we protect the environment.

It is important, in Kyoto, that we set up a system that will work -- one that will allow us to reduce our emissions at the lowest possible cost so that we can achieve the maximum protection of the environment. And it is also important that we send a clear signal to governments and industries so they can make significant investments in the new technologies that will be required if we are to achieve our ultimate goal. And finally, although those of us in the developed world must take the lead, everyone must participate in moving toward the solution.

I look forward to working closely with you and your colleagues on this most challenging and complex of environmental issues.

Thank you very much and I will be happy to answer any questions you may have.

Testimony

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Total Pages: 16

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EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
Washington, D.C. 20503-0001

Tuesday, October 7, 1997

LEGISLATIVE REFERRAL MEMORANDUM

TO: Legislative Liaison Officer - See Distribution below

Ron Peterson

FROM: Ronald K. Peterson (for) Assistant Director for Legislative Reference
OMB CONTACT: Robert J. Tuccillo
PHONE: (202)395-5609 FAX: (202)395-5836

SUBJECT: **STATE Qs and As on Global Climate Change**

DEADLINE: **11:00 AM Wednesday, October 8, 1997**

In accordance with OMB Circular A-19, OMB requests the views of your agency on the above subject before advising on its relationship to the program of the President. **Please advise us if this item will affect direct spending or receipts for purposes of the "Pay-As-You-Go" provisions of Title XIII of the Omnibus Budget Reconciliation Act of 1990.**

COMMENTS: State needs to provide these answers to the Senate Foreign Relations Committee prior to the Thursday 10/9/97 hearing.
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LRM ID: EHF280 **SUBJECT:** STATE Qs and As on Global Climate Change

RESPONSE TO
LEGISLATIVE REFERRAL
MEMORANDUM

If your response to this request for views is short (e.g., concur/no comment), we prefer that you respond by e-mail or by faxing us this response sheet. If the response is short and you prefer to call, please call the branch-wide line shown below (NOT the analyst's line) to leave a message with a legislative assistant.

You may also respond by:

(1) calling the analyst/attorney's direct line (you will be connected to voice mail if the analyst does not answer); or

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The following is the reponse of our agency to your request for views on the above-captioned subject:

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Questions for the Record Submitted by Chairman Hagel to
Under Secretary of State Timothy Wirth
Senate Foreign Relations Committee
Subcommittee on International Economic Policy,
Export and Trade Promotion
June 19, 1997

Senator Hagel

1. Q: **What enabling legislation might be necessary to implement any agreement that would mandate legally-binding emissions reductions on the United States?**

A: Any legally binding agreement would require Senate ratification of the protocol or other legal instrument itself. Any specific legislation to implement domestically the agreement would depend on the nature of the international agreement itself and the policies chosen to implement it domestically. At this time, we are still evaluating a wide range of options for domestic implementation and therefore cannot state with any specificity what implementing legislation might be required.

2 Q: **I understand a Department of Energy official made a presentation at a May 6, 1997 meeting of the Society of Automotive Engineers. At the meeting, this official reportedly said that to return to 1990 greenhouse gas emissions, this country would either have to increase average fuel efficiency to 70 mpg by 2005, or institute gasoline taxes 74 cents per gallon by 2005. Do you agree with the assessment of the Administration official?**

A: The Department official was providing a report based primarily on material developed for the *Policy Dialogue Advisory Committee to Assist the President in the Development of Measures to Significantly Reduce Greenhouse Gas Emissions from Personal Motor Vehicles.* This Presidential advisory committee considered ways to return personal transportation-sector greenhouse gas emissions to 1990 levels by 2005, 2015 and 2025. While this committee did not reach a consensus on the best policies to achieve these goals, substantial analytic work was performed including the information you asked about.

The official did not report at the Society of Automotive Engineers meeting that the U.S. needed to increase automotive efficiency to any specific level or that we would need a gasoline tax in order for the U.S. to stabilize U.S. greenhouse gas emissions at 1990 levels. Rather, what was said was that *if* one tried to return estimated future U.S. emissions from private motor vehicles to their 1990 levels by 2005 assuming the use of either fuel economy standards or a gasoline tax, that a 70 mpg standard or a 74 cent per gallon tax would be required. This is clearly not this Administration's policy.

The Administration favors a flexible approach to reducing emissions that would permit market forces to select the most cost-effective approaches. These should be aided by the availability of advanced technologies that joint government-industry research will provide. We believe there are other preferable approaches to reducing personal transportation emissions besides fuel economy standards or gasoline taxes. These options include the introduction of advanced technology vehicles (now under development - Partnership for a New Generation of Vehicles) and the use of low-greenhouse gas fuels such as cellulosic ethanol. We would note that the Department official concluded his presentation by saying that continued federal and private investment in these promising technologies was a prudent approach to reducing transportation sector emissions and that they were a more cost-effective approach than fuel taxes or fuel economy requirements.

3. Q: **Last year the Administration adopted a position supporting "legally binding commitments" on the United States to reduce greenhouse gas emissions. What entity do you envision enforcing these legally binding commitments on our government and our nation?**

A: The U.S. proposal calls for each Party to establish a system for national reporting and measurement of greenhouse gas emissions, as well as putting in place national compliance and enforcement programs relevant to implementation of its obligations. Thus, the primary responsibility for enforcement is at the national level. In addition, the U.S. proposal calls for the establishment of a review process, in which expert teams, coordinated by the Protocol Secretariat would assess Parties' implementation of their obligations. The Parties to the protocol, based on the results of such reviews, would have the responsibility of reviewing compliance, and determining what consequences (if any) should be applied in cases of non-compliance.

4. Q: **Do you intend any emissions trading scheme to apply equally to public and private entities? Would it apply to city and state governments? Would it apply to the Federal Government and our Armed Forces?**

A: The draft proposal does not establish a domestic system for emissions trading; that decision is left to each Party to determine on its own. However, the regime would permit individual Parties to allow private sector trading as well as sub-national entities such as local or state governments. The Administration has not yet taken a position with respect to the domestic implementation of the protocol in this regard.

5. Q: Has the Department of Defense conducted a study on the effect the treaty's restrictions would place on its activities?

A: DoD has a global climate change integrated product team (IPT) in place that is assessing the impacts of the negotiations on DoD activities; however, no conclusions have yet been reached.

6. Q: The U.S. draft protocol includes language referring to various automatic and discretionary "consequences for non-compliance with obligations." What exactly does this refer to?

A: In the U.S. view, a legally binding obligation will be essential to ensuring that countries actually lower their levels of emissions. Past experience has shown that in order to implement binding obligations, consequences for non-compliance also need to be developed. A number of alternatives are being considered for such consequences. We anticipate that they will range in severity according to the Articles for which non-compliance is determined. For example, different provisions might be imposed for non-compliance with monitoring than for non-compliance with meeting a budget. Different provisions may also be imposed for multiple incidents of non-compliance than for only a single incident. We believe that allowing non-compliance to be determined on a completely ad hoc basis will limit the effectiveness of the regime. To this end, we have proposed that the non-compliance provisions be made explicit through a decision by the Parties.

7. Q: The Administration opposes "differentiated" commitments by OECD countries. Yet, I understand the European Union has proposed a mechanisms whereby each of its member states would have a different commitment for percentage reductions. Is the Administration considering accepting an exception for the EU?

A: No. While we believe that the European Union (or any other Party or groups of Parties) may choose to undertake a series of agreements whereby emissions trading might be allowed, we do not believe that the "bubble" as proposed by the EU is an appropriate mechanism. Furthermore, while the Administration has recognized that differences do exist between countries, we do not believe it will be possible to negotiate these differences and reach a consensus on the outcome in time to conclude negotiations by December 1997 in Kyoto.

8. Q: I understand that Argonne National Laboratory conducted a study on "The Impacts of Potential Climate Change Commitments on Energy-Intensive Industries." That study was reportedly completed last November, but still has not been made public. Please explain why it has not been released.

– Are press reports accurate that the study found a devastating impact on the steel, aluminum, cement, chemical, petroleum, and forest products industries?

A. The Department sponsored a project at Argonne in which panels of industry representatives experts from academia, environmental groups, organized labor, the financial community, and government were asked to reflect on the possible industry met to discuss the possible impacts on industry output, employment, energy usage, technology, costs, prices, imports and exports.

The negative conclusions expressed by the participants were predicated on the specific energy price scenarios assumed in mid-1996, which do not reflect key policies advocated in international climate negotiations by the Clinton administration in the intervening year. For example, the assumed fuel price scenarios do not take into account the impact of multi-year emissions budgets, international emission trading, and joint implementation. If adopted, these provisions would lower the costs of achieving emissions reductions in the U.S. and other developed countries and would significantly lower the energy price increases assumed in the workshop scenarios. The Administration has also argued that the developing countries should assume additional obligations in the near future to reduce the projected rapid growth of greenhouse gas emissions. No such actions were reflected in the workshop scenarios.

A draft paper providing a personal interpretation of the workshops was circulated prior to completion of the report by an individual employee of Argonne National Laboratory. That paper was apparently prepared in advance of the participants' review of the workshop summaries to ensure that their input had been reported accurately, and prior to the lead authors' completion of the revised focus papers based on comments received at the workshops.

The final report, The Impact of High Energy Price Scenarios on Energy-Intensive Sectors: Perspectives from Industry Workshops, was issued on July 11, 1997. It includes an accurate and complete summary of the workshop findings, the full text of all the lead authors' papers, and the scenarios given to the participants.

9. Q: Regarding the Administration's draft report to the U.N. body that was set up to monitor the 1992 Framework Convention on Climate Change: I understand that this draft report says that the U.S. is unlikely to be able to return its greenhouse gas emissions to 1990 levels by the year 2000 for two reasons: First, U.S. energy prices are too low, and second, the U.S. economy is too strong. Is this correct, and if so, do you agree with this assessment?

A: This report was completed in final in August 1997, and submitted to the Convention Secretariat. Copies have been sent to your committee. That report states that several reasons are anticipated to lead to U.S. emissions in 2000 exceeding their 1990 levels: energy prices being lower than projected when the U.S. emissions reduction program was first established; Congress providing reduced funding from that proposed in the Administration program; and individual programs working less effectively than anticipated. While the economy did perform more robustly than expected, this factor is not considered likely to lead to significant increases in emissions beyond those projected.

10. Q: In follow-up to my previous question, this draft U.S. report also says that due to economic growth and population growth, U.S. energy consumption would have to be reduced 25% by the year 2010 to return greenhouse gas emissions to 1990 levels.
– What impact would this level of reduction in energy use have on U.S. economic growth?
-- How does the impact on the United States compare to that of our European and Japanese competitors? I would note that these countries are experiencing much weaker economic growth than the United States.

A: The report does not state that energy consumption would need to be lower – only that to maintain emissions at 1990 levels, emissions would need to be approximately 24% below projected levels. This could be accomplished through changes in efficiency in energy production and consumption, through fuel switching (away from emissions intensive fuels), through the development of new processes that produce fewer emissions, as well as through conservation and reduced energy consumption. No definitive economic analysis has been performed that can provide a guaranteed projection of the effects of such a program. However, most modelers and economists agree that a properly designed program would have little aggregate cost to the U.S. economy, although most recognize that there would be some distributive effects, with some sectors and regions of the country outperforming others. The costs of emissions reductions could be substantially reduced if market instruments such as emissions trading and joint implementation were allowed.

Projections for both Japan and Europe suggest that their economics are unlikely to grow at rates similar to that of the United States over the next decade. However, due to the greater efficiency of these economies (fewer emissions are produced per unit of GDP than in the United States), many economists have estimated that reductions in these countries will be more costly than in the United States. Overall GDP impacts from returning emissions to 1990 levels are thus estimated to be higher in both Europe and Japan than here.

11. Q: **You have stated the belief that technology will lower the costs of this proposed treaty to the U.S. economy. Can you identify which specific technologies will do so, and by how much?**

A: No. The Administration has rejected developing new technologies through a command-and-control type approach. Rather, we are seeking to develop appropriate market signals and maintain a robust marketplace to encourage our private sector to develop those technologies that will generate the greatest emissions reductions at the lowest cost. Historical rates of technology development have varied between 1 percent and more than 3 percent per year. While it seems likely that future development will proceed at similar rates, projecting the effects changes in technology will have on emissions reductions directly is fraught with ambiguity. Existing forecasts suggests, however, that costs with a greater rate of technological efficiency factored in will make it less expensive to achieve a 1990 level of emissions in 2010 than without relying on such changes. would

12. Q: **Is the Administration committed to submitting for Senate advice and consent any agreement on climate change reached at the Third Conference of Parties this December in Kyoto, Japan? Are there any circumstances under which the Administration would not submit to the United States Senate any such agreement?**

A: The Administration would anticipate submitting for Senate advice and consent to ratification any agreement adopted in Kyoto that would impose new legally binding commitments on the United States. We do not envision any circumstances in which such a new legal instrument would not be submitted to the United States Senate for Senate advice and consent to ratification.

Senator Kerry

1. Q: **Based on the current scientific knowledge, how much concern should we have about the problem of climate change? Is the Administration using the best available science in making policy decisions?**

A: The Administration's concern about climate change is predicated on the best available scientific information. This includes not only the work of the Intergovernmental Panel on Climate Change (a group of more than 2000 scientists who contributed to an international assessment of the science, impacts, response options and economic issues of climate change), but also on the work of the U.S. domestic scientific establishment as reflected in governmental and non-governmental publications. This body of information, which in its totality represents the vast majority of all the scientific work on this complex and difficult issue, suggests that without significant action, over the course of the next 100 years, we will be faced with substantial

changes in the world's climate system, which could have enormous impacts on the human and natural systems. The Administration views (and believes that Congress and the American people should view) this as a matter for grave concern – not only for the future when these impacts will be felt, but now, when the opportunity still exists to prevent such changes.

2. Q: **What is known about the impacts of possible climate change for the United States? In particular, is there any information available about the consequences of sea level rise, about changes in the availability of water and water resources, and possible implications for changes in disease vectors from a change in climate?**

A: Human health, natural ecological systems, and socioeconomic systems are all sensitive to both the magnitude and the rate of climate change. The Intergovernmental Panel on Climate Change (IPCC) concluded in its 1995 Second Assessment that, "With the growth in atmospheric concentrations of greenhouse gases, interference with the climate system will grow in magnitude, and the likelihood of adverse impacts from climate change that could be judged dangerous will become greater."

Sea level rise. Global tidal gauge data shows that worldwide sea levels have risen 4 to 10 inches over the last century. Tidal gauge data from the US shows that sea levels have risen by as much as 3 feet over the last century in Louisiana and parts of California and Texas, to 1 foot along most of the Atlantic and gulf coasts. In Los Angeles, sea level has risen about 4 inches over the last 100 years.

The level of the sea is affected by geological and climate factors, although climate has historically had more substantial impacts on global sea level. Throughout geologic history, the sea level has risen and fallen over 1000 feet. Globally, this phenomenon is due to changes in the shape and size of ocean basins, the amount of water in the oceans and the average density of sea water. Over the last 100 years, tide gauges used to determine global sea level trends have shown global sea level to have risen about 4-10 inches. This rise is caused by thermal expansion of ocean water and melting of land-based ice sheets and glaciers. Regional changes in sea level vary from the global average because of other factors such as the independently increasing or decreasing elevation of the land due to tectonic activity, compacting of sediments, or subsurface pumping of petroleum or water. The net effect is referred to as relative sea level rise. Along some of the US Coast, the relative sea level rise has been closer to 12 inches.

Previous relationships between climate and sea level, and increasing concentrations of greenhouse gases, form the basis for expecting an accelerated rise in sea level. Increasing concentrations of carbon dioxide, methane, and other gases released by human activities could raise the earth's average temperature. A warmer atmosphere would retain more water vapor, intensifying the hydrologic cycle in coastal areas and over open ocean. Snow and floating ice would retreat, decreasing the extent to which sunlight is reflected into space, causing additional warming. These two feedbacks would amplify the direct warming from the greenhouse effect. The increased warming would accelerate the rate of sea level rise by expanding ocean water,

melting mountain glaciers, and causing ice sheets in Greenland and Antarctica to melt or discharge ice into oceans, and by depleting groundwater tables.

According to the Intergovernmental Panel on Climate Change, rising global temperatures are responsible for at least 2 to 5 inches of sea level rise, due to thermal expansion of ocean water and the retreat of mountain glaciers.

Estimates of future sea level rise. The amount by which sea level will rise will vary by location. For the global average, it is projected that sea level will rise 20 inches by 2100 (6-38 inches). The amount by which sea level will rise will vary considerably for different segments of the US coast line. In some cases local sea level rise will exceed the global average, in other cases it will be less than the global average. The following are examples for a few locations:

Location	2050	2100
Galveston, TX	1.5 feet	3 feet
Miami Beach, FL	9 inches	1.5 feet
Los Angeles, CA	6 inches	1 foot
Boston, MA	1 foot	2 feet
Grand Isle, LA	2.5 feet	4.5 feet

Why is it a problem if sea level rises? Sea level rise will have a significant effect on the natural environment, infrastructure in developed areas, and on local economies. When we speak of impacts to the natural environment, we are referring to coastal wetlands that will be unable to keep pace with rising sea level, resulting in overall loss in wetland areas, especially in developed areas; loss of beaches due to an increased rate of erosion and inundation; loss of significant habitat in wetlands, estuaries, coral reefs, bays, and wilderness; saltwater intrusion into groundwater and upstream movement of the salt-line in surface water; and increased estuarine salinity that will reduce circulation and decrease the amount of flushing, resulting in an increase in water pollution.

Impacts to infrastructure include damage or destruction of housing, resorts, and other coastal development; flooding of transportation facilities such as bridges, railways, airports and marinas; disruption of utilities for electricity, communication, water supply and sewer systems; and loss of cultural or historical assets such as national parks, monuments and cemeteries.

Finally, the impacts to the local economy include the cost of prevention and protection for natural and manmade environments; the cost of loss and damage to natural and manmade environments due to storm surge, flooding, erosion and inundation; and the loss of industry and employment in tourism, local business, factories, shipping and commercial fisheries.

Coastal wetlands. As the sea level rises, coastal wetlands will be disrupted in a number of ways. These include inundation, erosion, and saltwater intrusion. Specific changes include conversion from one type of vegetation to another within particular wetlands, or conversion of wetlands to open water. Losses of wetlands at specific sites along the coast will depend on the slope of the

land throughout the wetland and adjacent dryland, and whether developed areas lie beyond the wetland limiting the vacant land necessary for new marsh to form.

There could be a substantial loss of coastal wetlands in the United States. Wetlands along the low-lying coasts of the Southeast from North Carolina in the Atlantic to Texas in the Gulf of Mexico are already subsiding due to compression of estuarine or deltaic sediments by new layers of sedimentary deposits. These areas may be either flooded or washed away as water levels rise. About half of the 5.5 million acres of coastal wetlands that remain in the US are found along the Gulf of Mexico, making the potential for loss great.

Salt water intrusion due to accelerated sea level rise will affect estuarine systems in some areas of the North Atlantic and Pacific Oceans, including Puget Sound, San Francisco Bay, and Tijuana Estuary.

Wetlands along highly developed coasts, including much of the Atlantic coast from Maryland to Massachusetts, may become quite vulnerable to climate change because control structures such as sea walls and bulkheads already form barriers to migration. Along undeveloped coasts, the land just above sea level into which wetlands could migrate is generally smaller than the area of wetlands at risk from climate change.

Thus, much of the coastal wetlands may slowly shrink until they are eliminated as the sea rises and pushes them back to the flood-control structures already erected or to be constructed to protect coastal properties.

The loss of coastal wetlands will have a significant effect on the human and natural environment. Coastal wetlands provide a variety of services, such as nursing grounds for many types of fish and shellfish, a resting place for migratory birds, and natural cleansing of ground and surface waters. These services will be diminished or eliminated. Coastal wetlands also protect inland areas from floods, storms and high tides. In many developing nations, wetlands provide the only effective barrier to surges from tropical storms.

Water resources. Climate change will likely have significant impacts on water quality and availability. Precipitation changes and increased evaporation can affect water supplies, water quality and drinking water, and water uses (e.g., hydropower, irrigation, fisheries).

It is expected that climate change will lead to an intensification of the hydrologic cycle. Not only is average global precipitation expected to increase, but the intensity of precipitation events will also likely increase leading to more floods. Droughts are also likely to be more severe due to increased evaporation and drier soils.

Although average global precipitation is expected to increase, there will be a regional "texture" to precipitation changes across the United States. Average annual water supplies may decrease significantly for large areas of the United States, resulting in lower levels in lakes, rivers, and aquifers. This would alter flood and shore erosion patterns, impair navigation, reduce hydropower generation, restrict irrigation and municipal water supplies, cause saltwater intrusion

into freshwater rivers and aquifers, and disrupt wetland and shore ecologies. The regions most vulnerable are the Great Basin, California, Missouri, Arkansas, Texas Gulf, Rio Grande, and Lower Colorado.

Changes in disease vectors. Infectious diseases are still the leading cause of death worldwide, killing over 17 million people in 1995, including nine million young children. Vector-borne diseases (i.e., diseases transmitted by insect "vectors" or small mammal "reservoir hosts") account for a large proportion of these deaths. For example, there are 350 to 500 million new cases of malaria annually; an estimated two million people die from malaria each year, including more than one million children in Africa. While there are relatively few cases of malaria in the United States, recent locally-transmitted cases in New Jersey, New York, and Texas demonstrate the continued risk for transmission of this disease.

The geographic range and life-cycles of pathogens and vectors (e.g., mosquitoes) which transmit disease are affected by climate. Many biological organisms and processes that contribute to the spread of infectious diseases are influenced by fluctuations in the weather, notably temperature, precipitation, and humidity. Outbreaks of infectious diseases (e.g., malaria, hantavirus, St. Louis Encephalitis) have been associated with specific weather patterns.

Frequently, outbreaks of infectious disease follow seasonal patterns related to the life cycle of disease pathogens and vectors. (Mosquitoes, for example, are dormant during one stage of their life cycle in order to survive winter or drought.) In this context, the projected rise in minimum temperatures (i.e., at night and during winter) relative to increases in average global temperature is of particular concern. The increased warming expected in temperate areas, such as North America, also favors the spread of infectious diseases to higher latitudes and altitudes.

The IPCC concluded in its 1995 Second Assessment that climate change would, in aggregate, increase the potential transmission of many vector-borne diseases. In North America, climate may become more suitable the northward spread of vector-borne infectious diseases, with potentially enhanced transmission dynamics due to warmer ambient temperatures. Conditions suitable to the transmission of diseases currently prevalent in the tropics (such as Dengue fever) may become more prevalent in areas of the southern U.S., such as Texas. (For example, recent work by Focks et al. [1995] suggests that the number of weeks during which weather conditions would be suitable for the transmission of Dengue fever would increase in many U.S. cities as average temperatures increase.) Other diseases, such as Rocky Mountain Spotted Fever (RMSF) may decline in the southern U.S. due to the intolerance of the tick vector to high temperatures and lower humidity. However, increased risk of both Lyme disease and RMSF, however, could be expected to be found at higher latitudes in Canada.

While health-care infrastructure may prevent a large increase in disease cases, climate change is expected to impose increasing demands and costs on the current public health system.

3. Q: What are other countries' position on the climate change issue? Other OECD countries? Are these countries taking action to mitigate climate change?

A: More than 160 countries are participating in the ongoing negotiation for a new agreement under the United Nations Framework Convention on Climate Change (FCCC). It is possible to group country positions into several different categories – although it must be recognized that each country has specific and often different circumstances that may distinguish it within its group. Six groups are discussed here: the European Union; the "JUSCANZ" group (including all OECD countries not part of the EU); the EITs (countries with economics in transition to market economies, including eastern Europe and the Former Soviet Union); the Alliance of Small Island States (AOSIS); the OPEC group; the big developing countries (including China, India, and Brazil), which strongly influence the positions of the developing country bloc.

EU With fifteen members states, the EU is often hard pressed to reach a consensus on some of the difficult issues in the climate change debate. However, they have announced their support for a target of Annex I Parties of a 15 percent reduction iO2 emissions by 2010, and a 71/2 percent reduction by 2005. Current data suggests that as a group, the EU will be close to returning to 1990 levels by 2000, although this is largely the result of significant reduction by Germany and the UK; most other countries will individually exceed 1990 levels at the end of the decade. Nearly all countries have taken actions to reduce emissions; all have submitted their first communication, and nearly half are in the process or have completed their second national communication detailing programs and policies that are being taken to mitigate climate change. As a bloc, this group supports a legally binding target, supports joint implementation (although only with countries that have a binding cap), and supports including advanced developing countries (specifically Mexico and Korea) in Annex I. They have argued that the next step should focus on developed country action. and that only following such steps should developing countries be obligated to act.

JUSCANZ (including Canada, Japan, Australia, New Zealand, Iceland, Norway, Switzerland). This group supports position closest to those of the United States. They have endorsed emissions trading, and joint implementation (although with some hesitation), they have endorsed the notion of a multi-year budget, and they have generally been supportive of action for developing countries (although Japan, Norway and Switzerland have been reluctant to push too hard on this front). As a group, these countries anticipate their 2000 emissions will exceed their 1990 levels by more than 10 percent, and each anticipates further growth unless new policies are initiated. Both Norway and Switzerland have proposed legally binding caps on emissions at 10 percent below 1990 levels by 2020. This group of countries has also been the most vocal in support of "differentiation," in which countries would take different levels of commitments as a function of national circumstances. For most. this means their own circumstances would dictate reduced levels of commitments from the Annex I average.

EITs This group of countries' emissions will be substantially below 1990 levels in 2000, and are not expected to return to 1990 levels until approximately 2010. They anticipate having emissions to "sell" under a trading regime – and have been strong supporters of a trading regime. These countries have supported maintaining the provisions in the FCCC that allow EITs some

"flexibility" in implementing their obligations, arguing that their recovery from the collapse of the early 1990's will take time and is a priority. While as a group they are taking some actions to reduce emissions, most actions are in the nature of energy efficiency improvements, and not actions specifically taken for climate change reasons.

AOSIS This group of 37 small island states and low lying coastal countries has been a strong supporter of stringent action to mitigate climate change. Threatened by sea level rise, many of these countries have maximum elevations of less than 3 meters above sea level. However, in spite of their strong rhetoric, these countries have not supported developing country commitments, arguing that developed countries are responsible for the problem and need to act first to find solutions. This group has advocated the most stringent target so far proposed: a 20 percent reduction in CO2 emissions by Annex I Parties below 1990 levels by 2005. They have opposed joint implementation, and have been ambivalent on the issue of emissions trading.

OPEC Concerned that efforts to reduce global emissions will lead to a global reduction in the amount of oil consumed, these countries have opposed action to address climate change. They have also introduced the concepts of a compensation fund, in which countries harmed by climate change mitigation efforts would be compensated for their economic hardship. To date, few countries outside of the OPEC group have supported this proposal. These countries have taken little action at home to reduce emissions, and none have yet released their first national communications detailing their greenhouse gas inventories. They have opposed joint implementation and been silent on the issue of emissions trading.

Big Developing Countries Those countries often orate the defining voice for the developing country caucus, in spite of protests from both AOSIS and OPEC. In spite of the projections of climate change which show significant damage to India, China and Brazil from significant climate change, these countries have long argued that efforts to solve the climate change problem are the sole responsibility of the developed world, which due to its large share of historic emissions, should also take on the bulk of the mitigation effort. The group has opposed joint implementation, been silent on emissions trading, and been adamantly opposed to any action by developing countries in the agreement in Kyoto. In spite of their rhetoric, many in this group have taken significant action to mitigate climate change. The United States has undertaken country studies with China, and has worked bilaterally with India and Brazil in their greenhouse gas inventory work, and in the development of policies and measures to reduce emissions. While emissions from each are anticipated to rise substantially as their economies grow, all have begun to move off the emissions intensive path predicted without these efforts.

4. Q: **What information is available on the impacts of joint implementation and emissions trading on the costs of mitigating climate change? What is the Administration doing to ensure that these cost-effective options are included in any agreement in Kyoto?**

A: All economic analyses done to date indicate a significant reduction in costs from the flexibility provided in both emissions trading and joint implementation. Some analyses done suggest that as much as 30 percent of the costs may be eliminated if emissions trading is allowed, and up to 70 percent of the costs may be eliminated if joint implementation is allowed. While these may be optimistic estimates, they provide a strong rationale for including both options in any agreement. It is in light of these kinds of analyses that the Administration has included both in its draft protocol, and that active diplomatic efforts are underway to persuade other countries to endorse these cost-saving approaches. A number of problems have been identified with both options – and it is addressing these concerns that has been the target of both our domestic and international effort. A number of projects in the U.S. Initiative on Joint Implementation are designed to address questions about "additionality" to insure that projects really produce environmental results, and are not merely repackaging of activities that would have occurred anyway. With respect to emissions trading, the United States has sponsored or co-sponsored a number of international workshops to develop methodologies for emissions trading, and to bring together those with expertise in trading programs (many of which were developed in the United

States) with representatives of other countries seeking information. We anticipate that these efforts will ultimately prove effective in bringing an international consensus to our proposals.

5. Q: **Please describe the Administration's efforts to seek input from the private sector, the environmental community, and other interested constituencies in developing its climate change policy.**

A: The Administration has maintained a long standing effort to obtain the views of various constituencies during the course of the climate negotiations. Open meetings typically have been held both before, during, and after major negotiating sessions to discuss relevant issues. Informal roundtables with both industry and environmentalists have also been held prior to major negotiating events. Within the past two months, the President has been directly involved in a series of meetings with scientists, industry and environmental leaders to discuss climate change. Various Cabinet officials have also been meeting with a broad range of constituency groups.