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Wind Energy Weekly

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GAS GROUP ATTACKS WIND; AWEA ISSUES RESPONSE

*NGSA Targets Economics and the Environment in
Criticizing Entire Wind Energy Industry*

The Natural Gas Supply Association (NGSA), a gas producers and marketers group based in Washington, D.C., as part of a sustained campaign against renewable energy, attacked wind energy as expensive and environmentally-damaging in a press release issued August 27. AWEA responded August 29 in a statement it said was aimed at "setting the record straight."

The NGSA release cited what it called wind's high cost, stating that wind costs 4.1 cents/kWh, or "almost 30% more than the cost of gas combined-cycle technology." When the 1.5 cents/kWh federal production tax credit (PTC) for wind is taken into account, NGSA said, wind-generated electricity costs nearly 70% more than gas-fired power.

AWEA, however, called NGSA's decision to complain about the PTC "most surprising," in view of long-standing, pervasive, and lucrative federal tax breaks for the oil and gas industry. Noted AWEA, "Extension of the [PTC] would cost \$14 million over the next five years... Meanwhile, the oil and gas industry will collect in excess of \$4

billion [or roughly 300 times as much] in tax breaks over four years (1996-2000) from items that include:

- the expensing deduction for oil and gas;
- the percentage depletion allowance;
- tertiary recovery well expensing; and
- alternative minimum tax relief.

It seems clear that without these generous government handouts, the price of electricity generated from natural gas would be significantly higher."

AWEA director of communications Tom Gray also called the wind-gas price comparison "misleading and bogus," noting, "It would cost consumers 70% more only if all gas generation were magically replaced today by wind. In the real world, this is something that would take many years to occur, during which time the price of gas could easily increase drastically as it has in the past. Even using NGSA's numbers, the price impact on the average household of a renewables portfolio standard

(see GAS, page 2)

Background on Issues

INTERNATIONAL NEGOTIATIONS

The Framework Convention on Climate Change was signed at the Rio "Earth Summit" in 1992. The current round of negotiations is scheduled to conclude in Kyoto this December. To date, the United States has advanced a three-part framework for the negotiations. We have argued for (1) binding emissions targets, (2) flexibility in achieving those targets (for example, through emissions trading among developed nations and "joint implementation" with developing nations), and (3) the participation of all countries. We have not yet proposed any specific targets or timetables. A relatively low-level negotiating session has been going on this week in Bonn and will continue next week.

Targets and Timetables

The European Union has proposed that developed nations cut back emissions 10-15% from 1990 levels by 2010. We have stated publicly that we believe this proposal is unrealistic. Other nations, including Australia, Japan and Canada, have expressed concerns about moving too far too fast, but have not put forward any specific targets. Several countries (including Australia, Japan and Norway) have supported "differentiated" targets, under which different developed countries would take on different obligations. The United States has opposed these proposals as unworkable.

Flexibility

The term "flexibility" has been used to refer to international emissions trading, joint implementation, banking and borrowing (applying extra emissions reductions from one period in another period) and multi-year targets (setting emissions targets for periods of two or more years, such as 2010-2020). Such policies can substantially reduce costs of compliance.

Our proposal for emissions trading among all developed countries has met with only limited support. However, the EU has proposed that its members be allowed to trade emissions among themselves (the "EU bubble"). We have insisted that all countries that all developed countries be allowed to trade emissions.

Closely related to international emissions trading is "joint implementation." In a typical case, a company in the developed world would invest in a renewable energy, energy efficiency or forestry project in a developing nation. Emissions avoided as a result of this investment could be applied to that company's obligations at home. Since emissions reductions are typically much cheaper in the developing world than they are in the developed world, significant efficiencies could result. Developing countries would gain benefits in the form of technology transfer and private sector

investment flows as well.

In spite of the potential benefits, most developed countries remain opposed to joint implementation (although support has grown significantly in Latin America). Many of these countries see joint implementation as a way for developed countries to avoid taking responsibility for reducing greenhouse gas emissions. In addition, some environmentalists are concerned that measuring project-based emissions reductions will be too difficult, and some in Congress are concerned that joint implementation will result in significant transfers of wealth overseas.

The U.S. business community has strongly supported joint implementation. Utilities have been among the most active participants in pilot projects to explore the feasibility of joint implementation.

Developing Country Commitments

This is the most difficult issue in the current round of negotiations. There is a vast gulf between the dialogue abroad (where the U.S. proposals for developing country participation are almost uniformly considered too aggressive) and at home (where Senator Byrd's resolution, calling for commitments beyond the U.S. proposal or the 1995 Berlin Mandate under which this treaty is being negotiated, passed the Senate recently 95-0).

Developed countries are responsible for more than 75% of the increase in greenhouse gas concentrations since the beginning of the Industrial Revolution. In the decades ahead, however, emissions from developing countries are expected to grow sharply. By 2035, developing country emissions are expected to exceed those from the developing world.

Per capita emissions vary widely. Carbon emissions from the United States are roughly 5 tons per person; from the OECD as a whole, roughly 3.5 tons per person; and from developing countries as a whole, roughly 0.5 tons per person.

The 1992 climate treaty established differentiated levels of commitments for developed and developing countries. It called upon developed countries to take the lead in addressing climate change and to aim to return emissions to 1990 levels by the year 2000. It called upon developing countries to adopt policies and measures to address climate change, but provided no aim for developing countries similar to the year 2000 goal. These differentiated commitments were intended to recognize both the unequal contribution of developed and developing countries to global greenhouse gas concentrations and the unequal capacity of those countries to control emissions.

In 1995, in Berlin, the Parties to the climate treaty agreed to negotiate further steps for controlling greenhouse gas emissions. The negotiating mandate calls on developed countries to set quantified emissions limits for the "medium term (e.g. 2005, 2010 and 2020)." In Berlin, the United States argued strongly that developing countries must participate meaningfully in negotiations over next

steps. There was little support for the U.S. position on this point, with many Parties noting the failure of most developed countries to take significant steps toward meeting the year 2000 goal. The Berlin Mandate states that there will be "no new commitments" for developing countries in the current round of negotiation, but that developing countries will be required to "advance the implementation of" their existing (non-binding) commitments.

In January, 1997, the U.S. submitted a draft protocol proposal. Provisions on developing countries included three elements, the most important of which is the "evolution" concept, which would require developing countries to enter into an agreement by 2005 to adopt legally binding emissions targets and would include a "graduation mechanism" under which developing countries would automatically incur obligations as their living standards increase.

DOMESTIC POLICIES

Your Cabinet and staff are currently in the process of shaping domestic policies options to address greenhouse gas emissions. Among the options receiving close attention are domestic emissions trading and technology programs.

Domestic Emissions Trading Programs

Under emissions trading programs (sometimes referred to as "cap and trade"), companies would be allowed to buy and sell the right to emit greenhouse gases. The US has had more experience with emissions trading than any other country. Examples include the Clean Air Act's acid rain program, under which utilities are allocated permits based on historical emissions of sulphur dioxide. Permits may be traded. Compliance costs under this program have been much less than expected, due to unforeseen factors. (Prior to passage, industry estimated compliance costs would be over \$1,000/ton. Government studies estimated costs would be around \$600/ton. Currently, allowances are trading on the Chicago Board of trade for around \$100/ton).

Among the issues to be addressed in designing a domestic emissions trading program:

- Where the constraint is imposed. A "primary fuel" trading program would limit the production or import of fossil fuels. A "sectoral" trading program would limit emissions from one or more key sectors (e.g., utilities, transport or heavy manufacturing).
- How permits are distributed. For example, permits could be parceled out to emitters based on historical emissions, auctioned, or some combination of the two. If auctioned, substantial revenues would be raised which, for example, could be recycled through a consumer and/or business tax cut, or used for transitional or technology programs).

An emissions trading program for greenhouse gases could potentially be bigger in scope (by an order of magnitude) than any existing emissions trading program. We are currently exploring

feasibility and implications.

Technology Programs

The cost of reducing greenhouse gas emissions between now and 2020 depends greatly on the ability to accelerate use of existing energy-efficient technologies. Over the longer-term, the solution to the climate change problem depends on developing and deploying new technologies that are even more efficient or are based on non-carbon energy sources.

A range of government programs might help accelerate technological change. Research and development programs generally aim to improve technologies by lowering production and operating costs. Large opportunities for cost-lowering research and development exist in buildings, transportation, combustion, renewables and sequestration (e.g., fuel cells, advanced industrial turbines, advanced diesel engines, and transportation biofuels). In addition, information dissemination programs assist businesses and consumers in identifying opportunities to reduce the energy intensity of their products or services (e.g., using more energy efficient light bulbs, insulation, appliances, etc.).

You have strongly supported technology programs with significant climate change benefits. Examples include:

Partnership for a New Generation Vehicle (PNGV)

The PNGV program joins the big three U.S. auto makers, federal agencies and many suppliers of materials and equipment in an effort to develop a more efficient car. The program's goal is to triple the fuel efficiency of passenger cars with no decrease in comfort or safety.

The Climate Change Action Plan (CCAP)

CCAP began in 1993 with a goal of returning total US greenhouse gas emissions to their 1990 levels by the year 2000. The plan includes about 50 initiatives covering all major greenhouse gas producing sectors of the US economy, including Energy Demand, Energy Supply, and Forestry. CCAP programs have reduced the rate of emissions growth, but not enough to achieve the programs goals. CCAP is a voluntary program that relies on partnerships and cooperation with industry and includes both government and private sector investment in new low-emissions, high-efficiency technologies. Agency participants include DOE, EPA, and USDA.

Biomass Energy Initiative

DOE and USDA are working with companies to demonstrate power projects for rural development and to improve technologies for converting crops to liquid and gaseous fuels. Pilot projects are running in New York, Minnesota and Iowa.

Million Solar Roofs Initiative

In your recent UN speech, you announced that DOE will lead an effort to place one million solar energy systems on the roofs of buildings and homes across the US by the year 2010. This will be accomplished by using existing federal grants, procurement, and other programs, and by working with local communities, businesses, state governments, utilities, and other groups to spur the sales of solar energy systems. In 2010, this initiative will avert emissions of carbon dioxide equivalent to those produced by 850,000 cars and will produce the same electrical generating capacity as 3-5 coal-fired power plants.

PCAST Energy R&D Panel

In response to your request, the President's Council of Advisors on Science and Technology is conducting a comprehensive and strategic review of U.S. energy R&D policies and practices "to ensure the United States has a program that addresses its energy and environmental needs for the next century". The group is examining energy efficiency, fossil, nuclear (fission and fusion), and renewable energy programs and budgets across the Federal government. Their assessment, including recommended actions, is expected by October.

Partnership for Advancing Technologies in Housing (PATH)

Our planned PATH initiative will have HUD, DOE, and NIST working with building suppliers, assemblers, insurance companies, and state and local regulators in an effort improve the quality of housing and meet ambitious environmental goals without increasing prices. Buildings are responsible for about a third of US greenhouse gas emissions (this total is rising) and 2/3 of US electricity consumption.

DOE's Industries of the Future Program

This is an industry/government partnership with the seven most energy-intensive U.S. industries, including chemicals, paper and pulp, steel, aluminum and petroleum. The program has reached technology agreements with each industry that focus the R&D expertise of our national labs on cutting energy use and pollution in each industry.

NATIONAL SURVEY
FREQUENCIES -- August 15, 1997

'97 SEP 14 PM6:55

Hello. My name is _____. I'm calling long distance from _____. We are conducting a public opinion survey and I would like to ask you some questions. We are not selling anything, and I won't ask you for a contribution or donation.
Could I please speak with the (male/female) 18 or older in your household who celebrated a birthday most recently?

SEX OF RESPONDENT

Male 48
Female 52

1. First, are you registered to vote at this address? [IF NO, ASK FOR A FAMILY MEMBER WHO IS. IF NONE, TERMINATE AND MARK TQ1 ON SAMPLE SHEET]
2. How much, if anything, have you heard or read about the issue of global warming? Would you say you have heard a great deal, some, not too much or nothing at all about global warming?

Great deal 25
some 46
not too much 21
nothing at all 8
don't know 0

3. Generally speaking, how serious of a threat do you think global warming is today, very serious, somewhat serious, not too serious, or not serious at all -- or don't you have an opinion on this?

very serious 24
somewhat serious 42
not too serious 12
not serious at all 7
don't know 14

4. Twenty years from now, how serious of a threat do you think global warming will be, very serious, somewhat serious, not too serious, or not serious at all -- or don't you have an opinion on this?

very serious 38
somewhat serious 23
not too serious 11
not serious at all 6
don't know 22

5. Do you think that global warming is an environmental problem that is happening now, do you think that global warming will happen in the future, or do you think that global warming will not happen -- or don't you have an opinion on this?

Happening now	50
will happen in future	24
will not happen	10
not sure/don't know	16

6. When cars, electric utilities [you-TILL-uh-teez] and some other industries burn oil, coal and gasoline they release carbon dioxide and other gases into the atmosphere. Some scientists say these gases trap heat in the atmosphere, causing the earth to warm. They say this makes the world hotter and increases the chances of all kinds of extreme weather. This effect is called global warming. Generally speaking, how serious of a threat do you think global warming is today, very serious, somewhat serious, not too serious, or not serious at all -- or don't you have an opinion on this?

very serious	29
somewhat serious	45
not too serious	14
not serious at all	7
don't know	5

7. And how serious of a threat do you think global warming will be in twenty years, very serious, somewhat serious, not too serious, or not serious at all -- or don't you have an opinion on this?

very serious	45
somewhat serious	27
not too serious	9
not serious at all	7
don't know	12

8. It has been proposed that the nations of the world agree to reduce their carbon dioxide emissions by 20 percent by the year 2005 in order to significantly slow down the rate of global warming. Do you favor or oppose this proposal or don't you have an opinion on this?
[IF FAVOR/OPPOSE, ASK:] Is that (favor/oppose) strongly or not so strongly?

Strong favor	55	72
not strong favor	17	
undecided	19	
not strong oppose	3	
strong oppose	6	9

9. Which comes closest to your own view:

[READ STATEMENTS/ROTATE STATEMENTS A AND B]

___ A. President Clinton should not take action on global warming because there are too many real problems that need attention right now 30

___ B. President Clinton should take action on global warming now because the problem is only getting worse and we cannot afford to take a wait-and-see approach 56

[READ LAST]

or don't you have an opinion on this? 14

10. Which of the following statements comes closest to your own point of view?

[READ STATEMENTS/ROTATE STATEMENTS A AND B]

___ A. Stricter regulations on the emission of carbon dioxide from the use of oil, coal and gasoline would go too far, and hurt the economy and cost jobs ... 18

___ B. Stricter regulations on the emission of carbon dioxide from the use of oil, coal and gasoline will help stop global warming, protect our health and safety, create new jobs through new technologies and are worth the cost 60

[READ LAST]

___ I'm not sure about this 22

11. With whom do you agree more?

[READ STATEMENTS/ROTATE STATEMENTS A AND B—BEGIN FIRST STATEMENT WITH “SOME” AND SECOND STATEMENT WITH “OTHER”]

A. Some/Other people say that most scientist agree that global warming is real and already happening. They say the only scientists who do not believe global warming is happening are paid by big oil, coal and gasoline companies to find the results that will protect business interests, just like the tobacco industry scientists who said cigarettes don't cause cancer.

B. Other/Some people say that scientists disagree among themselves that global warming is happening. They say there is no real evidence that carbon dioxide emissions from coal, oil and gasoline are causing global warming.

With whom do you agree more, those who say global warming is happening or those who say global warming is not happening? **[IF ANSWER GIVEN:]** Do you agree strongly or not so strongly?

strongly happening	53
not so strongly happening	22
Undecided/Don't Know/Not Sure	9
not so strongly NOT happening	8
strongly NOT happening	7

12. If a candidate for political office spoke out in support of reducing the threat of global warming, would you think he was forward-thinking and speaking to a real problem or would you think he was too interested in environmental issues and ignoring bigger problems?

Forward thinking	60
Ignoring bigger problems	26
Don't know	14

13. Let's say you agreed with a particular candidate on most issues and were of the same political party, however, that candidate voted against efforts to reduce the threat of global warming. Would you be likely to vote for or against that candidate?
[IF FOR OR AGAINST, ASK:] Is that very likely or somewhat likely to vote (for/against)?

strongly for	19
somewhat for	22
somewhat against	19
strongly against	18
don't know	22

BEGIN SPLIT SAMPLE A

I'm going to list some specific problems that some people say could happen as a result of global warming. After each please tell me how concerned you would be about that particular item -- would it be one of the things that would concern you most, would it make you feel very concerned, somewhat concerned, not too concerned or not concerned at all. If you are not sure how you feel about a particular item, please say so and we will go on.

	One of most	Very concern	Swht concern	Not too concern	Not at all	dk
[ROTATE BATTERY BY QUESTION Q.14-Q.22]						
__ 14. the spread of infectious diseases	19	51	14	7	6	3
__ 15. extinction of certain animal species like polar bears and sea turtles	13	38	28	10	9	2
__ 16. more extreme weather conditions such as drought, blizzards and hurricanes	16	41	25	9	7	2
__ 17. melting of the polar ice caps and glaciers causing the sea level to rise and the flooding of coastal communities	13	39	26	11	8	2
__ 18. crop failures, food shortages and famine caused by droughts and floods	20	48	19	5	7	1
__ 19. longer and hotter heat waves leading to more heat related deaths	15	38	29	9	7	2
__ 20. disruption of our fragile ecological [echo-LODGE-ick-al] balance threatening the web of life	14	42	26	5	8	4
__ 21. increased populations of pests and vermin, such as roaches, termites and rats	15	42	24	9	7	3
__ 22. destruction of natural habitats, including oceans and national parks like Glacier National Park and the Everglades	17	46	23	6	7	1
ASK LAST						
23. increased incidences of asthma and other respiratory problems	19	43	25	7	5	2

END SPLIT SAMPLE A. GO TO Q.34

BEGIN SPLIT SAMPLE B

I'm going to list some specific problems that some people say could happen as a result of global warming. After each please tell me how likely you think that problem is to occur as a result of global warming -- is that problem almost certain to happen, very likely, somewhat likely, not too likely, or not likely at all to occur as a result a global warming? If you are not sure how you feel about a particular item, please say so and we will go on.

	Almst certain	Very likely	Smwt likely	Not too likely	Not at likely	DK
[ROTATE BATTERY BY QUESTION Q.24-Q.32]						
__24. the spread of infectious diseases	12	20	26	16	11	15
__25. extinction of certain animal species like polar bears and sea turtles	15	31	27	12	8	7
__26. more extreme weather conditions such as drought, blizzards and hurricanes	22	32	25	7	9	5
__27. melting of the polar ice caps and glaciers causing the sea level to rise and the flooding of coastal communities	19	30	28	12	8	4
__28. crop failures, food shortages and famine caused by droughts and floods	19	30	28	12	7	4
__29. longer and hotter heat waves leading to more heat related deaths	20	29	29	11	7	3
__30. disruption of our fragile ecological [echo-LODGE-ick-al] balance threatening the web of life	17	30	27	13	7	7
__31. increased populations of pests and vermin, such as roaches, termites and rats	12	21	23	17	10	17
__32. destruction of natural habitats, including oceans and national parks like Glacier National Park and the Everglades	17	31	25	11	9	6
ASK LAST						
33. increased incidences of asthma and other respiratory problems	17	31	24	10	7	11

END SPLIT SAMPLE B. GO TO Q.34

RESUME ASKING EVERYONE

34. In trying to reduce the threat of global warming, do you think we should rely mainly on strict regulations to limit emissions of carbon dioxide, or do you think we should rely mainly on incentives that will cause the free market to discourage carbon dioxide pollution -- or don't you have an opinion on this?

[IF ANSWER GIVEN:] Do feel that way strongly or not so strongly?

Strongly regulations	31
Not so strongly regulations	6
Undecided	9
Not so strongly free market	9
Strongly free market	23
dk	21

35. Which comes closer to your own point of view:

[READ STATEMENTS/ROTATE STATEMENTS A AND B]

__A. The technology already exists to solve many of the problems that cause global warming, but big businesses like the oil and auto industries are preventing them from reaching consumers because it is more profitable to keep things the way they are 52

__B. Solving the problems that cause global warming will mean developing new technologies to reduce our use of oil, coal and gasoline, which will cost billions of dollars 29

[READ LAST]

or don't you have an opinion on this? 19

Now I'm going to list some of the specific proposals that have been made to decrease the use of oil, coal, and gasoline in order to reduce the threat of global warming. For each item I read, please tell me if you favor or oppose each one. If you aren't sure how you feel about any specific item, just say so and we will go on.
[FOLLOW ALL "FAVOR" OR "OPPOSE" WITH:] Do you strongly (FAVOR/OPPOSE) or only somewhat (FAVOR/OPPOSE) that?

[ROTATE BY QUESTION Q.36-Q.49]

SPLIT SAMPLE A

	strong favor	swhat favor	swhat oppose	strong oppose	DK
__36. Increase taxes on gasoline by 50 cents a gallon to discourage the use of oil, coal and gasoline, and in exchange, give every taxpayer a \$250 rebate on their income taxes	14	17	12	46	10

SPLIT SAMPLE B

__37. Increase taxes on gasoline by 75 cents a gallon to discourage the use of oil, coal and gasoline, and in exchange, give every taxpayer a \$375 rebate on their income taxes	11	14	14	52	9
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RESUME ASKING EVERYONE

__38. Require companies to pay for the right to pollute at lower levels than they do now and use the money raised to develop new technologies that will reduce carbon dioxide emissions even further	36	31	11	16	7
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__39. As part of the deregulation of the utility [you-TILL-uh-tee] industry, require utility companies to offer alternative energy services that are more efficient and environmentally clean, such as solar and wind power	54	28	6	6	6
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__40. Establish a limit on the total amount of carbon dioxide pollution that can be emitted in the United States that is lower than current levels. Individual businesses would bid at a government auction for the rights to pollute. Businesses could buy and sell these pollution rights to one another on the free market. This would allow them to chose between reducing their carbon dioxide emissions or paying to continue to pollute	12	17	15	42	14
--	----	----	----	----	----

__41. Give cash incentives like tax credits and rebates to individual households that upgrade to more energy efficient appliances like refrigerators and air conditioners	59	26	5	7	3
---	----	----	---	---	---

SPLIT SAMPLE A

__42. Cut military spending and earmark the money instead for research and development of alternative fuels and technologies	22	19	20	32	7
--	----	----	----	----	---

ROTATE ONTO NEXT PAGE

	strong favor	swhat favor	swhat oppose	strong oppose	DK
SPLIT SAMPLE B					
__43. Increase the tax on gasoline by 10 cents per gallon and earmark the money for research and development of alternative fuels and technologies	25	23	13	36	3

RESUME ASKING EVERYONE

__44. Have the United Nations establish a worldwide limit on carbon dioxide emissions that is lower than current levels. Each U.N. member country would be allocated the right to discharge a certain amount of carbon dioxide pollution. Countries could buy and sell these pollution rights to one another. This would allow them to chose between reducing their carbon dioxide emissions or paying to continue to pollute	12	20	17	39	12
__45. Provide tax incentives to utility [you-TILL-uh-tee] companies to encourage them to sell environmentally clean energy, such as solar and wind power, to consumers	52	29	7	8	5
__46. Shift money from developing new highways and roads to building public transportation systems such as new bus routes and commuter railways	32	29	14	17	9
__47. Prevent countries from using U.S. foreign aid to build factories and power plants that emit excessive carbon dioxide pollution, and instead, use this foreign aid to help these countries build environmentally clean power plants and factories	49	26	7	11	6
__48. Increase taxes on industrial energy use by 5 percent	22	29	14	22	13
__49. Require higher fuel efficiency and cleaner burning engines in all new cars	64	22	5	6	2

	One Of most	very eff	swhat eff	not too eff	not at all	DK
SPLIT SAMPLE B						
__57. Increase the tax on gasoline by 10 cents per gallon and earmark the money for research and development of alternative fuels and technologies	6	20	34	16	21	3

RESUME ASKING EVERYONE

__58. Have the United Nations establish a worldwide limit on carbon dioxide emissions that is lower than current levels. Each member country would be allocated the right to discharge a certain amount of carbon dioxide pollution. Countries could buy and sell these pollution rights to one another. This would allow them to chose between reducing their carbon dioxide emissions or paying to continue to pollute	4	11	28	19	30	8
__59. Provide tax incentives to utility [you-TILL-uh-tee] companies to encourage them to sell environmentally clean energy, such as solar and wind power, to consumers	11	33	41	6	5	4
__60. Shift money from developing new highways and roads to building public transportation systems such as new bus routes and commuter railways	9	23	34	14	14	5
__61. Prevent countries from using US foreign aid to build factories and power plants that emit excessive carbon dioxide pollution, and instead, use this foreign aid to help these countries build environmentally clean power plants and factories	11	31	36	8	9	6
__62. Increase taxes on industrial energy use by 5 percent . . .	7	17	36	17	16	7
__63. Require higher fuel efficiency and cleaner burning engines in all new cars	19	44	25	5	5	2

SPLIT SAMPLE C

64. How willing would you be to pay 5 dollars more per month to buy environmentally clean energy such as solar and wind power from your electric utility company in order to cut down on emissions of carbon dioxide and reduce the threat of global warming -- very willing, somewhat willing, somewhat unwilling or very unwilling or don't you have an opinion on this?

very willing	44
somewhat willing	36
somewhat unwilling	5
very unwilling	9
not sure	7

END SPLIT SAMPLE C. GO TO Q.67

SPLIT SAMPLE D

65. How willing would you be to pay 10 dollars more per month to buy environmentally clean energy such as solar and wind power from your electric utility company in order to cut down on emissions of carbon dioxide and reduce the threat of global warming -- very willing, somewhat willing, somewhat unwilling or very unwilling or don't you have an opinion on this?

very willing	38
somewhat willing	34
somewhat unwilling	10
very unwilling	12
not sure	6

END SPLIT SAMPLE D. GO TO Q.67

SPLIT SAMPLE E

66. How willing would you be to pay 20 dollars more per month to buy environmentally clean energy such as solar and wind power from your electric utility company in order to cut down on emissions of carbon dioxide and reduce the threat of global warming -- very willing, somewhat willing, somewhat unwilling or very unwilling or don't you have an opinion on this?

very willing	25
somewhat willing	36
somewhat unwilling	11
very unwilling	18
not sure	10

END SPLIT SAMPLE E. GO TO Q.67

THANK YOU. THE REMAINING QUESTIONS ARE FOR STATISTICAL PURPOSES ONLY.

RESUME ASKING EVERYONE

67. Generally speaking, do you think of yourself as a Republican, a Democrat, an independent, or something else?

[IF REPUBLICAN OR DEMOCRAT ASK:] Do you consider yourself a strong (Republican/Democrat) or a not so strong (Republican/Democrat)?

[IF INDEPENDENT ASK:] Would you say that you lean more toward the Republicans or more toward the Democrats?

strong Republican	15	36
not so strong Republican	13	
indep. leans Republican	8	
independent	15	
indep. leans Democratic	7	
not so strong Democrat	14	
strong Democrat	17	38
dk/na/other	11	

68. Do you consider yourself very liberal, somewhat liberal, moderate, somewhat conservative, very conservative or haven't you thought much about this? [IF MODERATE ASK:] Do you tend to lean toward the liberal or conservative side?

very liberal	9
somewhat liberal	17
moderate, leans liberal	7
moderate	13
moderate, leans conservative	9
somewhat conservative	23
very conservative	11
dk/na	11

69. What is your age?

18-29	16
30-39	19
40-49	24
50-59	16
60+	24
na	2

70. What was the last level of schooling you completed?

less than high school graduate	4
high school graduate	26
some college	31
college graduate	25
post graduate	12
na	2

71. Are you Hispanic or of Spanish descent?
- | | |
|-----|----|
| yes | 7 |
| no | 90 |
| dk | 3 |
72. Are you black, white, Asian, or some other race?
- | | |
|-------|----|
| black | 9 |
| white | 79 |
| Asian | 2 |
| other | 7 |
| na | 4 |
73. Do you have children, 18 years old or younger living at home?
- | | |
|------------|----|
| Yes | 38 |
| No | 61 |
| refused/NA | 1 |
74. How would you describe the area in which you live--Do you live in a city with over a million people, in a smaller city, in a suburban area outside a city, in a small town, or in a rural area?
- | | |
|-------------------|----|
| City (1 million+) | 12 |
| Smaller city | 20 |
| Suburban area | 21 |
| Small town | 26 |
| Rural area | 20 |
| (Don't Know) | 1 |
75. Is your job or that of anyone in your household dependent on the oil industry, chemical industry or auto industry ?
- | | |
|-----|----|
| yes | 19 |
| no | 80 |
| dk | 1 |
76. In which of the following ranges does your family income fall?
- | | |
|-------------------|----|
| below \$12,000 | 5 |
| 12 to 20 thousand | 12 |
| 20 to 30 thousand | 13 |
| 30 to 40 thousand | 17 |
| 40 to 50 thousand | 13 |
| 50 to 75 thousand | 15 |
| above 75 thousand | 12 |
| na | 12 |
77. What is your zip code? _____

That completes our public opinion survey. Thank you very much for your time and cooperation, and have a pleasant (day/evening).

Research G

✓
Science News, May 4, 1991

May 4, 1991

SECTION: Vol. 139 ; No. 18 ; Pg. 278; ISSN: 0036-8423

LENGTH: 578 words

HEADLINE: NAS: act now to reduce global warming; National Academy of Sciences report

BYLINE: Walker, Tim

BODY:

Despite uncertainties in the science of predicting global climate change, the National Academy of Sciences (NAS) urges immediate action to curb greenhouse-gas emissions by reducing fossil-fuel consumption, promoting energy conservation, and improving solar and nuclear-energy technologies. For a very low cost, says NAS President Frank Press, the United States could reduce its greenhouse-gas emissions by 10 to 40 percent.

According to White House Science Adviser D. Allan Bromley, the NAS recommendations "are very similar to actions already taken or being proposed by the Bush administration." Both Press and Bromley testified before the Senate Committee on Commerce, Science and Transportation last week.

"The possibility of ecological disaster due to an increase in global temperature is sufficient reason to act now," Press warned. Outlining recommendations in "Policy Implications of Greenhouse Warming," an NAS report released April 10, he advocated a variety of low-cost steps aimed at reducing emissions of the major greenhouse gases -- carbon dioxide, methane, chlorofluorocarbons and nitrous oxide.

For instance, the academy report recommends adopting nationwide energy-conserving changes in building codes for residential and commercial structures, boosting the average automobile-fuel efficiency 18 percent (to 32 miles per gallon) and substituting compact fluorescent lights for incandescent bulbs in homes and businesses.

Together, the measures described in the new report are designed to head off a predicted 1 degree to 5 degrees C increase in global temperature by the year 2050, Press said. Enactment of these steps -- which the report estimates would cost between \$ 4 billion and \$ 30 billion -- could reduce the heat-trapping equivalent of 3.6 billion metric tons of carbon dioxide emissions per year, or about one-third of last year's U.S. greenhouse-gas emissions.

However, the report cautions that even at reduced emission rates, total greenhouse gases might still increase if population and industrial activity increase faster than predicted.

The NAS recommendations "parallel" actions specified in the President's National Energy Strategy released in February, Bromley testified. But committee member Sen. Albert Gore Jr. (D-Tenn.) disagreed, charging instead that many administration policies are "simply in opposition to the recommendations in this report." He warned Bromley that "history will judge the Bush administration harshly if its current inactivity on global warming continues."

While the NAS report stopped short of calling for penalties and higher taxes for major producers of greenhouse gases -- which some European nations have imposed -- environmental groups generally approve of the new recommendations. "This report should remove any lingering doubts that more time is needed to study global warming before we act," says William A. Nitze, president of Alliance to Save Energy.

Though most environmental groups support the NAS report's call for increased funding for development of new renewable technologies, many also object to some of the report's higher-cost recommendations, including the replacement of most fossil-fueled power plants with a new generation of lightwater nuclear reactors now under development. "We are strongly opposed to any effort that puts forth nuclear power as a panacea for the greenhouse effect," says Eileen Quinn of the Union of Concerned Scientists.

SIC: 9611 Admin. of general economic programs

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LANGUAGE: ENGLISH

LOAD-DATE: October 05, 1995

"The United States needs to realize that although unilateral actions can contribute significantly to the reduction of greenhouse gases ... national efforts alone would not be sufficient to eliminate the problem," the report said.

Carbon dioxide, the principle greenhouse gas, is a waste produced mainly by burning gasoline, oil, coal and other carbon-based fuels. Thus, reducing the burning of these fuels can reduce the amount of carbon dioxide in the atmosphere.

Other greenhouse gases include chlorofluorocarbons, or CFCs, which are used principally as refrigerants and in manufacturing, and halons, which are used in fire extinguishers. Methane, or natural gas, is another major greenhouse gas. It enters the atmosphere from agriculture practices, landfills, some types of natural decay and oil field leaks.

LANGUAGE: ENGLISH

September 10, 1997

'97 SEP 10 PM12:51

MEMORANDUM FOR: Todd Stern

FROM: Susan L. Bassow

RE: National Academy of Science 1991 study, *Policy Implications of Greenhouse Warming*

Here is the National Academy book from 1991 that you described on the phone. Peter Backlund and I scanned through it and concluded the following.

We refer you to the table on page 59, and the discussion on page 105-106.

To summarize, the NAS 1991 study concludes that the potential emissions reduction per year is 1200 million metric tons at a cost of less than or equal to zero. That is a reduction of 26% of our CO₂ emissions in 1990. Another 600 million metric tons can be reduced with a net benefit to low cost.

	US emissions of carbon (million metric tons of C per year)	US emissions of CO ₂ (million metric tons of CO ₂ per year)	Potential emissions reduction (million metric tons of CO ₂ equivalent per year)	Percent reduction
1990	1237	4536	1200	26%
1995	1422	5214		

Keep in mind, that the NAS study may not be the most authoritative source.

Susan Bassow
6-6083

Research C

POLICY IMPLICATIONS OF GREENHOUSE WARMING

Policy Implications of Greenhouse Warming—Synthesis Panel

Committee on Science, Engineering, and Public Policy

National Academy of Sciences
National Academy of Engineering
Institute of Medicine

NATIONAL ACADEMY PRESS
Washington, D.C. 1991

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council (NRC), whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the panel responsible for this report were chosen for their special competences and with regard for appropriate balance. This report is the result of work done by an independent panel appointed by the Committee on Science, Engineering, and Public Policy, which has authorized its release to the public.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee and by the Committee on Science, Engineering, and Public Policy. Both consist of members of the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine.

The study reported here was supported by the U.S. Environmental Protection Agency. It also received support from the National Research Council Fund, a pool of private, discretionary, nonfederal funds that is used to support a program of Academy studies of national issues in which science and technology figure significantly. The NRC Fund consists of contributions from a consortium of private foundations including the Carnegie Corporation of New York, the Charles B. Culpeper Foundation, the William and Flora Hewlett Foundation, the John D. and Catherine T. MacArthur Foundation, the Andrew W. Mellon Foundation, the Rockefeller Foundation, and the Alfred P. Sloan Foundation; and the Academy Industry Program, which seeks annual contributions from companies that are concerned with the health of U.S. science and technology and with public policy issues with technological content.

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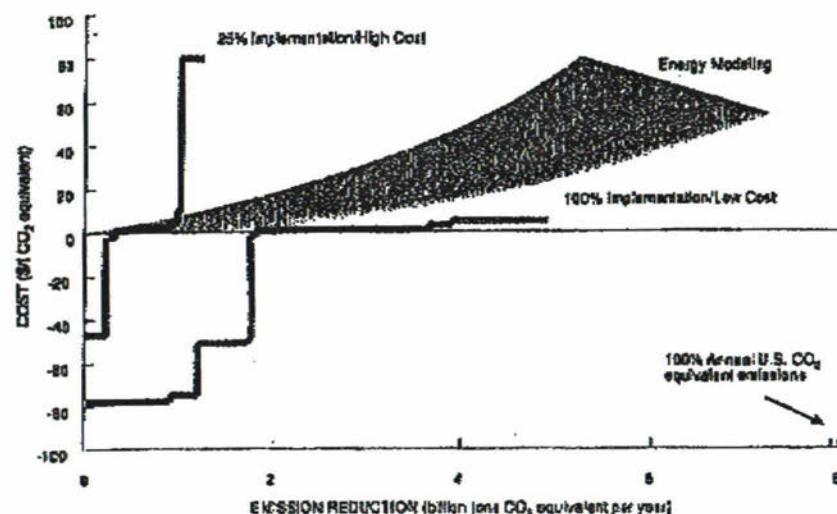


FIGURE 6.4 Comparison of mitigation options using technological costing and energy modeling calculations.

SOURCE: Chapter 11 of the report of the Mitigation Panel.

"100% Implementation/Low Cost" assumes complete implementation of each option (100 percent implementation) combined with the low range of cost estimates for that option (low cost). This line indicates the upper bound that could be achieved with all options shown. A complete analysis would calculate appropriate implementation rates for each option. That is beyond the scope of this study. It should be realistic to achieve emission reduction and cost results somewhere between the two lines in Figure 6.3.

As pointed out earlier in this chapter, technological costing and energy modeling sometimes yield different results. For this reason, both are presented in Figure 6.4. The "100% Implementation/Low Cost" and "25% Implementation/High Cost" curves are repeated from Figure 6.3, and the range typical of energy modeling is shown. As can be seen from Figure 6.4, the United States should be able to achieve substantial reduction in greenhouse gas emissions at low cost, or perhaps even a small net savings.

IMPLEMENTING MITIGATION OPTIONS

An array of policy instruments of two different types are available: regulation and incentives. Regulatory instruments mandate action and include controls on consumption (bans, quotas, required product attributes), produc-

tion (quotas on products or substances), and factors in design or production (efficiency, durability, processes). Incentive instruments are designed to influence decisions by individuals and organizations and include taxes and subsidies on production factors (carbon tax, fuel tax) and on products and other outputs (emission taxes, product taxes), financial inducements (tax credits, subsidies), and transferable emission rights (tradable emission reductions, tradable credits).

Interventions at all levels could effectively reduce greenhouse warming. For example, individuals could reduce energy consumption, recycle goods, and reduce consumption of deleterious materials. Local governments could control emissions from buildings, transport fleets, waste processing plants, and landfill dumps. State governments could restructure electric utility pricing structures and stimulate a variety of efficiency incentives. National governments could pursue action in most of the policy areas of relevance. International organizations could coordinate programs in various parts of the world, manage transfers of resources and technologies, and facilitate exchange of monitoring and other relevant data.

The choice of policy instrument depends on the objective to be served. Although this analysis of mitigation options does not include all possibilities, the panel is hopeful that it does identify the most promising options. This analysis provides the beginnings of a structure and a process for identifying those strategies that could appropriately mitigate the prospect of greenhouse warming.

CONCLUSIONS

There is a potential to inexpensively reduce or offset greenhouse gas emissions in the United States. In particular, the maximum feasible potential reduction for the options labeled "net benefit" and "low cost" in Table 6.2 totals about 3.6 billion tons (3.6 Gt) of CO₂-equivalent emissions per year. (Here, as elsewhere in the report, tons are metric.) This is a little more than one-third of the total 1990 greenhouse gas emissions in the United States and represents an optimistic upper bound on what could be achieved using these options.

A lower bound can be estimated from Figure 6.4. Arbitrarily using a cutoff of between \$10 and \$20 per ton of CO₂-equivalent emission reduction would produce a level of about 1 Gt of CO₂-equivalent emissions per year, or a little more than 10 percent of current greenhouse gas emissions in the United States.

This analysis suggests that the United States could reduce its greenhouse gas emissions by between 10 and 40 percent of the 1990 level at very low cost. Some reductions may even be at a net savings if the proper policies are implemented.

TABLE A.4 Estimated 1985 Global Greenhouse Gas Emissions from Human Activities

	Greenhouse Gas Emissions (Mt/yr)	CO ₂ -equivalent Emissions* (Mt/yr)	
CO₂ Emissions			
Commercial energy	18,800	18,800	(57)
Tropical deforestation	2,600	2,600	(8)
Other	400	400	(1)
TOTAL	21,800	21,800	(66)
CH₄ Emissions			
Fuel production	60	1,300	(4)
Enteric fermentation	70	1,500	(5)
Rice cultivation	110	2,300	(7)
Landfills	30	600	(2)
Tropical deforestation	20	400	(1)
Other	30	600	(2)
TOTAL	320	6,700	(20)*
CFC-11 and CFC-12 Emissions			
TOTAL	0.6	3,200	(10)
N₂O Emissions			
Coal combustion	1	290	(>1)
Fertilizer use	1.5	440	(1)
Gain of cultivated land	0.4	120	(>1)
Tropical deforestation	0.5	150	(>1)
Fuel wood and industrial biomass	0.2	60	(>1)
Agricultural wastes	0.4	120	(>1)
TOTAL	4	1,180	(4)
TOTAL		32,880	(100)

*CO₂-equivalent emissions are calculated from the Greenhouse Gas Emissions column by using the following multipliers:

CO ₂	1
CH ₄	21
CFC-11 and -12	5,400
N ₂ O	290

Numbers in parentheses are percentages of total.

*Total does not sum due to rounding errors.

NOTE: Mt/yr = million (10⁶) metric tons (t) per year. All entries are rounded because the exact values are controversial.

SOURCE: Adapted from U.S. Department of Energy. 1990. *The Economics of Long-Term Global Climate Change: A Preliminary Assessment—Report of an Interagency Task Force*. Springfield, Va.: National Technical Information Service.

CO₂ that would produce the same amount of forcing at the surface is calculated. This is the CO₂ equivalent for that specific concentration of the other greenhouse gas. The respective costs per ton for different options can then be compared directly. It is important to recognize, however, that these calculations allow comparison only of initial contributions. They do not account for changes in energy-trapping effectiveness over the various lifetimes of these gases in the atmosphere.

35. What mitigation options are most cost-effective?

The panel ranks options for reducing greenhouse gas emissions or removing greenhouse gases from the atmosphere according to their cost-effectiveness. Some of these options have net savings or very low net implementation costs compared to other investments. The options range from net savings to more than \$100 per metric ton of CO₂-equivalent emissions avoided or removed from the atmosphere. The most cost-effective mitigation options are presented in Table A.5.

36. What are examples of options with large potential to reduce or offset emissions?

The so-called geoengineering options have the potential of substantially affecting atmospheric concentrations of greenhouse gases. They have the ability to screen incoming sunlight, stimulate uptake of CO₂ by plants and animals in the oceans, or remove CO₂ from the atmosphere. Although they appear feasible, they require additional investigation because of their potential environmental impacts.

37. How much would it cost to significantly reduce current U.S. greenhouse gas emissions?

It depends on the level of emission reduction desired and how it is done. The most cost-effective options are those that enhance efficient use of energy: efficiency improvements in lighting and appliances, white roofs and paving to enhance reflectivity, and improvement in building and construction practices.

Figure A.4 compares mitigation options, and Table A.5 gives the panel's estimates of net cost and emission reductions for several options. It must be emphasized that the table presents the panel's estimates of the *maximum* technical potential for each option. The calculation of cost-effectiveness of lighting efficiency, for example, does not consider whether the supply of light bulbs could meet the demand with current production capacities. Nor does it consider the trade-off between expenditures on light bulbs and on health care, education, or basic shelter for low-income families. In addition, there is a danger of some "double counting." For example, in the area of energy supply both nuclear and natural gas energy options assume re-

TABLE A.5 Comparison of Selected Mitigation Options in the United States

Mitigation Option	Net Implementation Cost ^a	Potential Emission ^b Reduction (1 CO ₂ equivalent per year)
Building energy efficiency	Net benefit	900 million ^c
Vehicle efficiency (no fleet change)	Net benefit	300 million
Industrial energy management	Net benefit to low cost	500 million
Transportation system management	Net benefit to low cost	50 million
Power plant heat rate improvements	Net benefit to low cost	50 million
Landfill gas collection	Low cost	200 million
Halocarbon-CFC usage reduction	Low cost	1400 million
Agriculture	Low cost	200 million
Reforestation	Low to moderate cost ^d	200 million
Electricity supply	Low to moderate cost ^d	1000 million ^e

^aNet benefit = cost less than or equal to zero

Low cost = cost between \$1 and \$9 per ton of CO₂ equivalent

Moderate cost = cost between \$10 and \$99 per ton of CO₂ equivalent

High cost = cost of \$100 or more per ton of CO₂ equivalent

^bThis "maximum feasible" potential emission reduction assumes 100 percent implementation of each option in reasonable applications and is an optimistic "upper bound" on emission reductions.

^cThis depends on the actual implementation level and is controversial. This represents a middle value of possible rates.

^dSome portions do fall in low cost, but it is not possible to determine the amount of reductions obtainable at that cost.

^eThe potential emission reduction for electricity supply options is actually 1700 Mt CO₂ equivalent per year, but 1000 Mt is shown here to remove the double-counting effect.

NOTE: Here and throughout this report, tons are metric.

SOURCE: Chapter 11 of the Mitigation Panel report.

placement of the same coal-fired power plants. Table A.5, however, presents only options that avoid double counting. Finally, although there is evidence that efficiency programs can pay, there is no field evidence showing success with programs on the massive scale suggested here. Thus there may be very good reasons why "negative cost options" on the figure are not implemented today.

The United States could reduce its greenhouse gas emissions by between 10 and 40 percent of the 1990 levels at low cost, or perhaps some net savings, if proper policies are implemented.

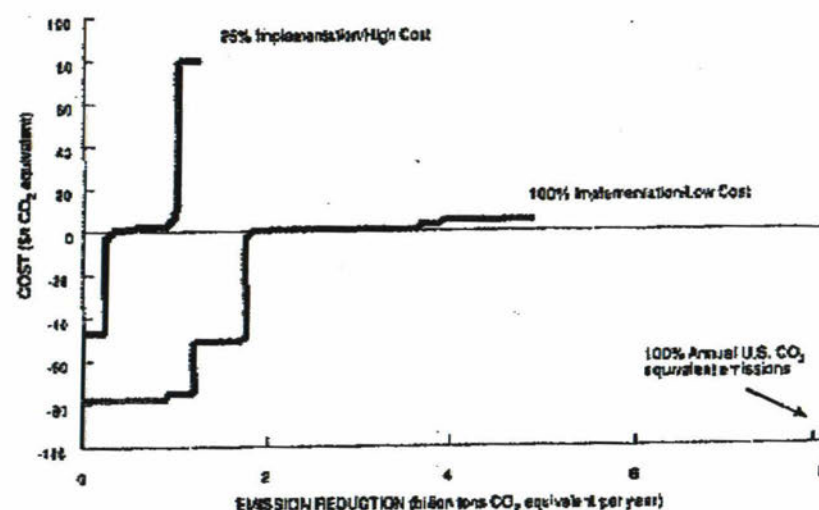


FIGURE A.4 Comparison of mitigation options. Total potential reduction of CO₂-equivalent emissions is compared to the cost in dollars per ton of CO₂ reduction. Options are ranked from left to right in CO₂ emissions according to cost. Some options show the possibility of reductions of CO₂ emissions at a net savings.

SOURCE: Chapter 11 of the report of the Mitigation Panel.

ADAPTING TO ADDITIONAL GREENHOUSE WARMING

38. Will human and natural systems adapt without assistance?

Farmers adjust their crops and cultivation practices in response to weather patterns over time. Natural ecosystems also adapt to changing conditions. The real issue is the rate at which human and natural systems will be able to adjust.

39. At what rates can human and natural systems adapt?

Many human systems have decision and investment cycles that are shorter than the time in which impacts of climate change would become manifest. These systems in the United States should be able to adjust to climate change without governmental intervention, as long as it is gradual and information about the rates of change is widely available. This applies to agriculture, commercial forestry, and most of industry. Industrial sectors with extremely long investment cycles (e.g., transport systems, urban infrastructure, and major structures and facilities) or requiring high volumes of water may require special attention. Coastal urban settlements would be

Research**THE BUSINESS COUNCIL****FOR** '97 SEP 10 PM5:35
SUSTAINABLE ENERGY '97 SEP 10 PM5:35

1200 18th St., N.W. Ninth Floor Washington, DC 20036

FAX COVER PAGE

To: Todd Clamm Fax: 456-2215	Date: September 10, 1997 Phone:
From: Michael Marvin Lisa Jacobson	For Information Call: (202) 785-0507
Pages: 2 (including this one)	Fax Number: (202) 785-0514

R



**The
Business Council
for
Sustainable
Energy**

1200 18th Street, NW
Ninth Floor
Washington, DC 20036

Phone 202-785-0507
Fax 202-785-0514

To: Todd Stern
Fr: Michael Marvin
Lisa Jacobson
Re: Research supporting a 20% reduction in GHG emissions through use of energy efficiency, renewable energy and improvements in energy production technologies or operations
Date: September 10, 1997

"Although national and global estimates are uncertain, present day win-win opportunities have the potential to reduce energy consumption and associated emissions by at least 20%, and in many sectors by as much as 40% or so -- all with a net savings in costs. Energy efficiency measures, fuel switching, and increasing use of renewable energy sources in rural areas are examples of win-win options." (pg. 9 of 47, on-line version)

The quote is from the Provisional Draft of *The World Bank Energy and Environment Strategy Review*, which was released for public comment on July 22, 1997.

This draft report is "not for citation", but a bibliography is provided at the end of the document.

The draft report is available on line at <http://geei.org/eespaper.txt>. A virtual consultation at this web site is currently being conducted.

Please call with any questions. Hope this is helpful.

Southeast: Climate Change Vulnerabilities and Impacts

The Southeast is a complex region including wetlands, coastal zones, agricultural and forestry areas, and urban regions, and rapid population growth is already providing significant stresses on fragile regional ecosystems, making the Southeast vulnerable to climate change. For example, in 1870, the population of south Florida was about 100; currently, the same region, which includes Dade, Broward, and Palm Beach counties, has a population exceeding 5.2 million people. The Southeast has more than 50% of the country's barrier islands and 85% of the nation's coastal wetlands, as well as more than 80% of the direct hits from hurricanes. The region provides our country with a variety of crops, fisheries, and wood products:

- Fisheries, including shrimp and other shellfish, comprise a \$1 billion annual business
- Loblolly pine plantations and other forestry activities constitute a \$XX industry
- Oranges and other fruit trees constitute a \$XX industry

Much of the region's growth is in coastal areas, increasing the risk from frequently occurring extreme weather events. Hurricane Andrew in 1992 killed 58 people, and cost \$30 billion, and Hurricane Fran in 1996 killed 36 people, and cost at least \$5 billion. Louisiana's Barrier Islands are vanishing. These islands shelter important coastal wetlands that serve as nurseries for many fish and shellfish. The Florida Everglades have already been significantly altered by human activities. Approximately half of the ecosystem has already been lost or severely altered in the past century due to drainage for agriculture and urban development, and nitrogen inputs from agricultural run-off.

Likely Impacts

- *Extreme climate events.* The Southeast is becoming increasingly vulnerable to extreme events including hurricanes, floods, drought, ice storms, heat waves, and tornadoes because of rapid population growth and development in vulnerable coastal locations.
- *Coastal areas.* Sea level rise will intensify the coastal areas' vulnerability to storm surges and extreme events. Up to 1000 feet of Florida beach could be lost from a ?? rise in sea-level.
- *Water resources.* The demand for water is beginning to exceed the available water supply, and competition for water uses is beginning to intensify. Climate variability and change exacerbate this competition for water.
- *Forestry.* Forest production will be impacted by both shifts in temperature regimes, as well as precipitation, increasing the difficulty of forest management. There may be marked shifts in forest species composition.
- *Agriculture.* Irrigation is not currently prevalent in southeastern agriculture, meaning that the area's agriculture systems are ill prepared for the more intense droughts expected from climate change.
- *Urban areas and human health.* Climate variability and change, especially warmer temperatures, will exacerbate air quality problems.
- *Parks and public lands.* Non-native and invasive species are problematic. Areas like the Everglades are already stressed by invasive species, and will further be hit with rising sea level. Up to a third of the park is vulnerable to sea-level rise of one foot. Much of the mangroves of the area are severely at risk from sea-level rise.

Great Plains: Climate Change Vulnerabilities and Impacts

The Great Plains states produce much of our nation's wheat and beef supplies, and are highly vulnerable in the face of the region's frequently dry climate. The region is bounded on the west by the Rocky Mountains, on the north by Canada's southern border, on the south by the edge of the desert/scrub ecosystem, and on the east by the edge of the bluestem grassland area. The Great Plains include parts of 10 states (MT, ND, WY, SD, NE, CO, AR, NM, OK, and TX), occupy about one third of the landmass of the conterminous United States, and are home to 6.2 million inhabitants.

Agriculture is the base of the economy in the Great Plains, despite the constraints of the dry and variable environment. Most of the farmers are wheat producers, but livestock operations are increasing.

- Over 90% of the land in the Great Plains is in farms and ranches, and 75% is cultivated.
- The Great Plains states account for 51% of the nation's wheat, 40% of its sorghum, 36% of its barley, 22% of its cotton, 14% of its oats, and 13% of its corn.
- The region produces 40% of the nation's cattle.

All sectors of life in the Great Plains are dependent on the very limited water supply in the region. Water shortages there are already a problem. Water sources in the area include rain; surface waters such as rivers, streams, and lakes primarily from snowmelt; and deep aquifers such as the Ogallala aquifer. Agricultural water needs often exceed rainfall, so irrigation water supplied from the deep aquifers is already common; however, overdraft of the Ogallala aquifer has already caused the water table to drop, a problem which could become even more severe in the future.

Likely Impacts

- *Water shortages.* As climate change leads to warmer conditions and an intensified hydrological system, the soils of the area are anticipated to further dry. The simultaneous drop in aquifer levels, greater run-off from extreme downpours, and shorter duration of snow cover will exacerbate the water problem in the region. The need for irrigation may rise while water supplies are simultaneously diminishing.
- *Water quality.* There are already problems of salinization of water in the region, and climate change is anticipated to aggravate the problem.
- *Soil degradation and erosion.* Soil fertility in many regions is declining, and increased intensity of farming may lead to even lower soil quality. Better soil tillage practices would simultaneously improve soil fertility, soil carbon storage capacity, and soil moisture holding capacity.
- *Disease and pest impacts on agriculture and cattle.* Climate-stressed crops or cattle will be more vulnerable to pests; new pests and diseases may emerge.
- *Recreation, Wildlife and Fisheries.* Riparian areas (prairie potholes) are extremely vulnerable to warmer and drier climate, and are intensively used by hunters, anglers, and birdwatchers.
- *Native species.* Climate change will disrupt and stress ecosystems, providing opportunity for more pest weed invasions. Native species will face increasing levels of competition from introduced species, such as cheat grass, Japanese brome, Russian thistle, and leafy spurge. Economic losses from these invasives can be great: for example, in North Dakota alone, economic losses from the leafy spurge exceed \$14.4 million per year.

Pacific Northwest: Climate Change Vulnerabilities and Impacts

The dependence of the NW on a reliable supply of water creates a significant regional vulnerability to climate change. The availability of adequate water supplies is directly tied to the amount, timing, and type of regional precipitation (snow or rain). Model projections indicate that NW regional consequences of warming are likely to include changing patterns of precipitation and drought, changes in timing of runoff, and increased inundation of coastal areas (that are already subsiding in some cases) from sea-level rise. Such changes, and in particular the expected disruption of the regional water cycle, pose significant threats to NW ecosystems and economic activities; forests, freshwater ecosystems, agriculture, industrial processes, hydroelectric energy production, and urban centers all depend on adequate supplies of water.

- Agriculture is critical to the regional economy. The NW leads the nation in potato and apple production, and over 50 additional crops are grown in significant quantities.
- Commercial timberlands cover 36% of the region's land area, producing half of the nation's softwood lumber and plywood.
- Hydroelectricity constitutes 14% of the energy consumed and about 60% of the energy generated in the region.

Impacts in one sector may trigger subsequent changes across other sectors, impacting the quality and quantity of water available to other components of this highly integrated watershed.

Likely Impacts

- Peak runoff comes earlier in the spring because of more rain and less snow in the winter, and late winter to early spring flow is enhanced, increasing the chance of spring flooding.
- There is reduced summer and early fall flow, particularly in west-side rivers (i.e., west of the Cascades Mountain range), due to the warmer and drier summer climate. Lower flows are detrimental to fisheries and threaten irrigation water supplies needed for agriculture.
- In the Columbia River basin, there will likely be an overall decrease in annual run-off, with increased competition among hydropower production, fisheries protection, and irrigation needs.
- Forests and rangelands face increased drought stress, pest outbreaks, and fires, along with shifts in forest zones and composition, and possible increases in blow-downs from wind storms. In addition to their economic and recreational importance, NW forests sequester more carbon per acre than any other ecosystem in the world. Loss of forest = loss of carbon sink.
- Freshwater fisheries will be affected, with west-side salmon migration and spawning hurt by decreased summer and fall run-off and fish habitat and egg-smolt survival hurt by increased wintertime river flows.
- The rate of coastal inundation and saltwater intrusion to freshwater ecosystems could be increased by sea-level rise. Olympia is already having drainage system problems and has incurred substantial mitigation costs from sea-wall construction to prevent flooding.
- Coastal erosion, landslides and bluff failures are also major risks to ecosystems and urban centers, and coastal development. Eleven major delta's in the region have decreased by 78% in the recent past. Existing wetlands will disappear faster than new ones appear, leading to loss of coastal habitat for outmigrating salmon, spawning oceanic species, and mammals and seabirds.

Alaska: Climate Change Vulnerabilities and Impacts

Alaska's dependence on natural resources makes it highly vulnerable to climate change. Global warming is most pronounced in northern regions, and probable consequences include drying of Alaska's interior, inundation of fragile coastal delta areas, and, most seriously, melting of permafrost, which is already underway. The Fisheries, Petroleum, Forestry, and Tourism industries together make up ?? of the Alaskan economy; all are likely to be significantly affected by climate change.

- The value of Alaska fisheries in 1995 was over \$1.4 billion, excluding processing.
- Petroleum production and infrastructure taxes account for about 85% of state revenue.
- 70% of US parklands are in Alaska, and tourism brings about ?? to the state each year.

The superficial assertion that warming of cold regions like Alaska is desirable ignores the fact that such regions face 100-200 years of severe ecological upheaval during the transition to a fundamentally different environment. Significant climate change has already occurred in Alaska.

- Average temperatures have increased statewide, with summers in the interior becoming much warmer and drier (Fairbanks summer temperatures are increasing at a rate of 3°C/100 years, while summer precipitation has decreased by 17% over the last 100 years).
- Over the last ten years, the growing season has become longer at high latitudes (45°-70° North).
- Continuous permafrost has warmed 2 to 4°C over the last century, and all permafrost measurement sites in Alaska warmed between the mid-1980's and 1996.

Likely impacts:

- Continuation of Alaskan warming will lead to the disappearance of most discontinuous permafrost over the next 100 years. In the many cases the ground level can collapse by up to 5 yards or more, leading to significant damages to ecosystems and human infrastructure.
- Houses, roads, airports, military installations, pipelines, and any other facility built on ice-rich permafrost are at risk. Over \$5 million has been spent over the last several years in a failed effort to reconstruct and maintain less than a mile of road near the University of Alaska Fairbanks.
- Ecosystem effects include destruction of trees and caribou habitat; clogging of salmon spawning streams; reduction in forested areas; expansion of lakes and wetlands; and increased rates of coastal and riverbank erosion, slope instability, landslides and erosion.
- The melting of permafrost and the warming of tundra will lead to the release of carbon and methane deposits from the formerly frozen lands, which could make them an additional source of atmospheric greenhouse gases.
- Forest impacts associated with warming and drying include increased damage from blow-downs, pest outbreaks in coastal forests, and drought-induced mortality, insect-caused mortality, and severe forest fires in the boreal forests.
- Numerous low-lying coastal delta areas are threatened by erosion from increased runoff and inundation from a combination of rising sea-level and storm surges made more severe by decreased sea-ice. Such disruption of coastal ecosystems could have severe consequences for animal habitats, and native settlements and subsistence activities.

Research C

The Associated Press

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June 14, 1991, Friday, AM cycle

SECTION: Washington Dateline

LENGTH: 749 words

HEADLINE: Report Examines Ways of Reducing U.S. Effects on Global Warming

BYLINE: By PAUL RECER, AP Science Writer

DATELINE: WASHINGTON

BODY:

There are simple and relatively painless ways that the United States could reduce emissions of greenhouse gases nationwide by about 40 percent, the National Academy of Sciences said in a report Friday.

The report said that actions such as switching to more efficient light bulbs in homes and businesses, improving energy use in buildings and industry, and phasing out gas-guzzling cars would drop America's polluting gases perhaps by 40 percent.

"It is readily apparent that a significant reduction in 1990 emissions can be achieved at relatively low cost," said Thomas Lee, chairman of a committee that spent two years studying ways the nation could lower the risk of climate change due to global warming.

Arthur H. Rosenfeld, a University of California, Berkeley, professor and one of the 19 co-authors of the report, said all of the measures could be accomplished with no change in the American life style and with little or no net cost.

"All of these investments will save you money and they save huge amounts of carbon dioxide," he said.

Carbon dioxide and some other manmade gases set loose in the atmosphere are known to trap the sun's heat energy near the Earth, in much the same way as glass panes trap heat in a greenhouse.

These gases have been increasing in the planet's atmosphere since the rise of the industrial age and many scientists now believe that the Earth can overheat if the trend continues.

The scientists' study examined dozens of measures the country could follow to reduce greenhouse gases. The report puts the options into three categories based on their cost and their potential for reducing the target gases.

Category 1, the cheapest approach, "are things that would have no impact on our life style," said Rosenfeld. Most of these measures center on reducing the demand for electricity and gasoline.

Category 2 options include measures that are more expensive and could cause significant social or industrial changes. These include forced changes in transportation systems, such as reducing available inner city parking to cause greater use of mass transit by commuters; forced changes in agricultural practices; forced changes in auto design, and mandatory switching in the types of fuels used by industry and power companies.

In category 3 are options that would either screen sunlight or increase the natural absorption of carbon dioxide. These include shading the Earth with space mirrors or fleets of balloons, or by shooting dust into the stratosphere with naval guns or rockets. To absorb more carbon dioxide, the committee said forests could be planted and nutrients dumped into the ocean to trigger a bloom of sea plants.

"Although some of these proposals have an aura of science fiction, they do have a potentially huge ability to mitigate against greenhouse warming," said Lee, a professor emeritus from Massachusetts Institute of Technology. Some of the category 3 measures, he said, could have dangerous side effects and "a great deal of research is needed before their feasibility can be fully understood."

Lee said "there is no single silver bullet" to avoid the risk of global warming for the planet, and he noted that the ultimate approach probably will include a mixture of the measures explored by the committee.

He also said there remains a great deal of scientific uncertainty about how serious greenhouse warming will become and the U.S. response to the problem may be adjusted as more is learned about the phenomenon.

The report said that although the United States is the world's largest producer of carbon dioxide and other greenhouse gases, the problem of global warming must be combatted by every nation.

"The United States needs to realize that although unilateral actions can

contribute significantly to the reduction of greenhouse gases ... national efforts alone would not be sufficient to eliminate the problem," the report said.

Carbon dioxide, the principle greenhouse gas, is a waste produced mainly by burning gasoline, oil, coal and other carbon-based fuels. Thus, reducing the burning of these fuels can reduce the amount of carbon dioxide in the atmosphere.

Other greenhouse gases include chlorofluorocarbons, or CFCs, which are used principally as refrigerants and in manufacturing, and halons, which are used in fire extinguishers. Methane, or natural gas, is another major greenhouse gas. It enters the atmosphere from agriculture practices, landfills, some types of natural decay and oil field leaks.

LANGUAGE: ENGLISH

Research

**Department
of the Treasury**

to: Todd Stern

**Office of the
General Counsel**

room: _____ date: August 5, 1997

'97 AUG 5 PM 5:28

Todd,

Attached are the materials I mentioned to you over the weekend. I hope you find them helpful.

Best to you and Jen.

Neal

Neal

Neal S. Wolin
Deputy General Counsel
Room 3000
Phone 622-0283

July 3, 1997

To: Treasury participants in climate change workgroups

From: Jon Gruber, Deputy Assistant Secretary for Economic Policy

Subject: **Background material on global climate change**

Here is a selection of articles and briefing materials on the economics and science of climate change. In each section, the first items summarize the issues, and should be read first. For more material on any of the topics covered here, please contact Ray Squitieri of my staff at 622-1301 or on the LAN.

The economics of climate change

"Climate change issues brief," prepared by the Office of Economic Policy, 5/97.

Articles from the *Economist*

"Smoke," 4/8/95
"Global warming and cooling enthusiasm," 4/1/95
"Stay cool," 4/1/95
"Cool costing," 3/6/93
"Whose world is it, anyway?" 5/30/92

Articles on general economic principles

"A Framework for climate change policy," Michael Toman, *Resources for the Future*, spring 1997. Guidelines for thinking about risks and rational policies.

"Global Environmental Forces," Thomas C. Schelling, *Energy: Production, Consumption, and Consequences*, 1990. A look at climate change from the perspective of a century hence; explains why international agreement is unlikely.

"Reflections of the Economics of Climate Change," William D. Nordhaus, *Journal of Economic Perspectives*, fall 1993. A comparison of benefits and costs of greenhouse gas abatement.

The Science of Climate Change

"Global warming: what we know and what we don't know," briefing by Dan Albritton, NOAA, 1996; concise illustrated summary.

"Greenhouse gases," briefing by Bob Watson, OSTP for 6/93 White House Conference on Climate; summary of scientific issues.

[untitled], briefing by Rosina Bierbaum, OSTP, 1997; relation between greenhouse gas emissions and concentrations.

Appendix: economic models of the costs of climate controls

"Assessing the cost of greenhouse abatement," Ray Squitieri, *Regulation*, fall 1992; description of different schools of climate models.

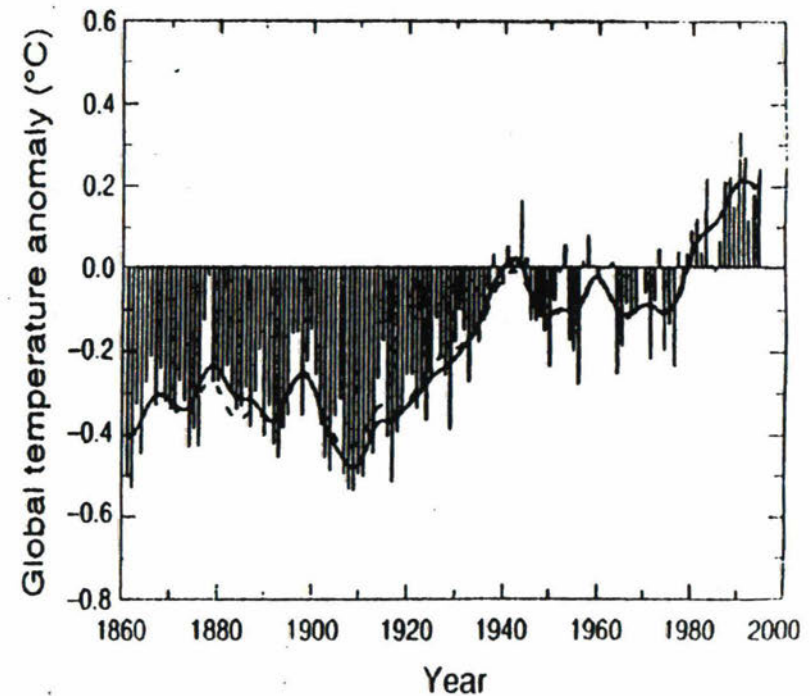
"A Review of mitigation cost studies," (summary and graphs) J.-C. Hourcade et al., Chapter 9 in *Climate Change 1995--Economic and Social Dimensions of Climate Change*, Intergovernmental Panel on Climate Change (IPCC), 1996; detailed results.

Climate Change
Issues Brief
May, 1997

Evidence of Climate Change

- During the 20th century:
 - Average surface temperature has increased by one-quarter to one-half degree C.
 - Sea level has risen 4 to 10 inches.
- What causes warming?
 - Natural greenhouse gases (GHGs) trap heat from sunlight
 - Without these gases, the earth's temperature would average only 5 degrees F.
 - Concentrations of GHGs increasing because of human activities, chiefly burning fossil fuels.

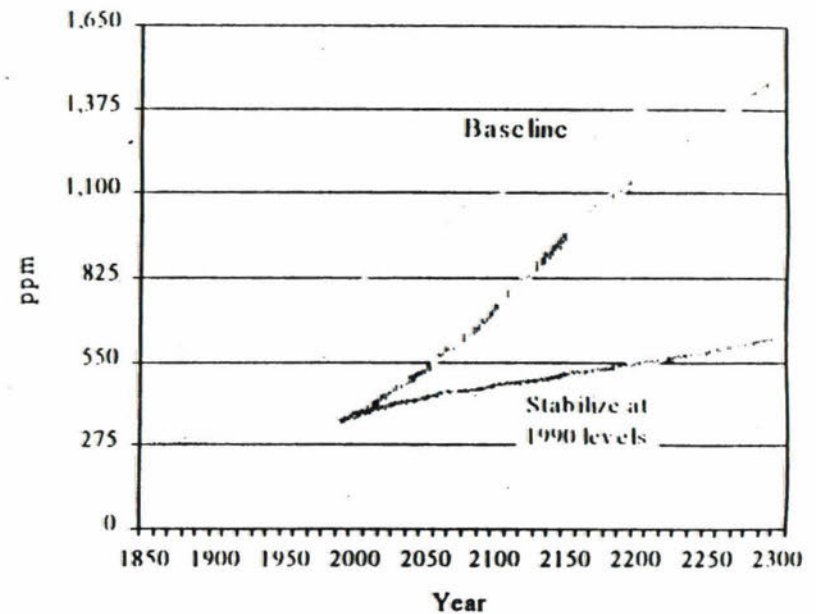
Combined Land-Surface Air and Sea Surface Temperatures
Temperatures from 1861 to 1994 relative to 1961 to 1990



Prospects for Future Warming

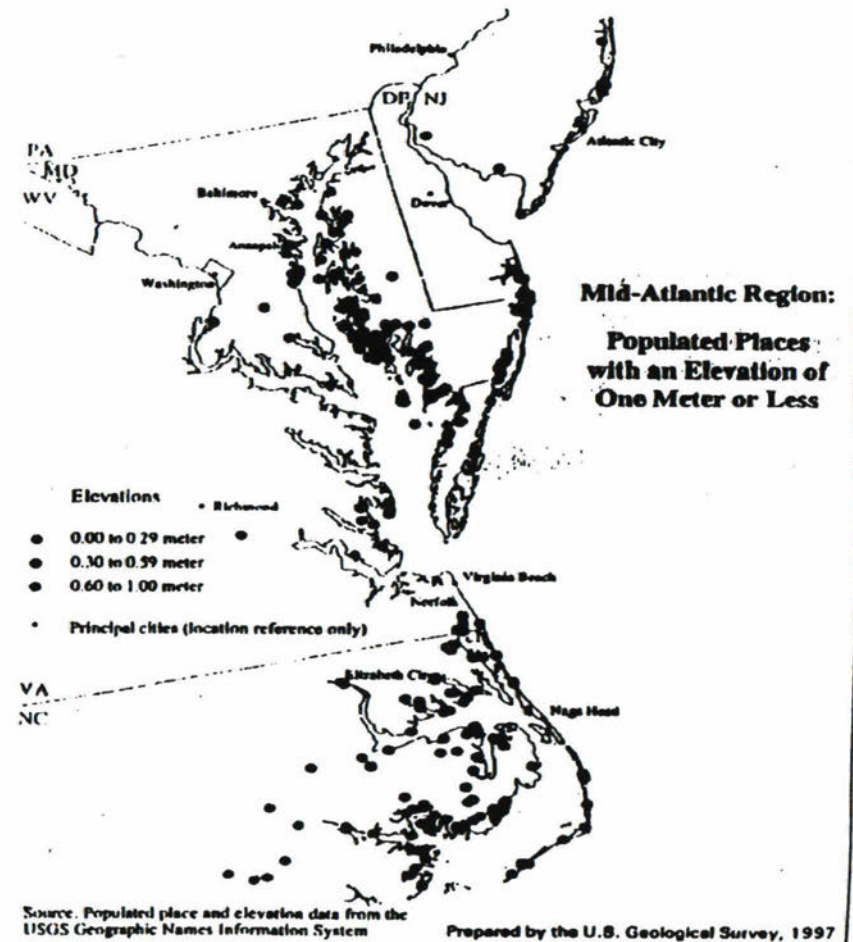
- CO₂ concentration levels in the earth's atmosphere are now 30 percent higher than pre-industrial levels.
- Predicted to rise to almost 3 times pre-industrial levels toward the end of the 21st century and continue to rise thereafter.

Atmospheric Concentrations of CO₂



Effects of Warming

- Sea level is expected to rise about 20 inches in the next century.
 - Along Atlantic and Gulf Coasts, this could inundate about 5000 square miles of dry land and an additional 4000 miles of wetland.
 - Changes in water resources would occur, including runoff and the frequency and intensity of floods and droughts.
 - Some places would become wetter, some dryer.
- US growing zones would move northward.
- Some argue tropical diseases would spread.

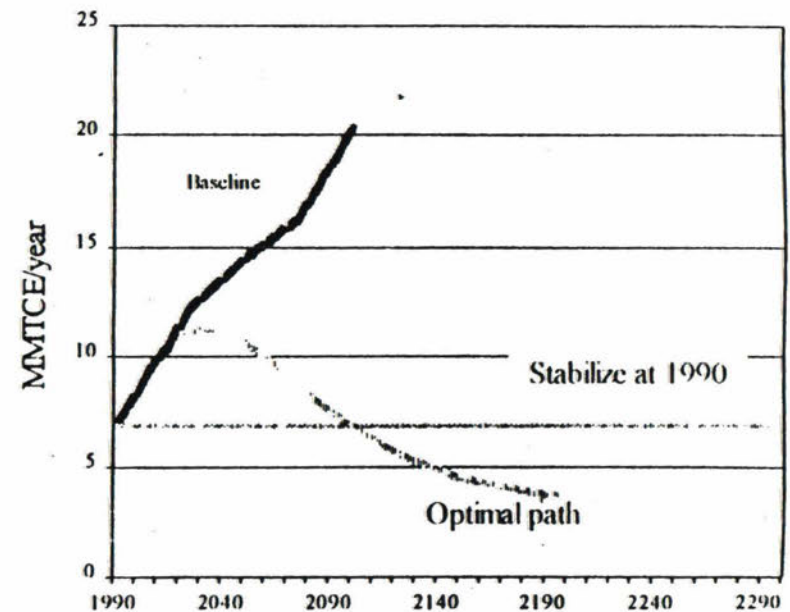


History of International Negotiations

- 1992 Rio Conference voluntary target: **1990 emissions levels by the year 2000.**
 - Most countries will not achieve target.
 - Britain, Russia, Germany can due to economic & political changes.
 - Developing countries not required to reduce emissions.
- **Kyoto, December 1997:** Measures for “medium term”, 2010-2020 Are they
reg'd to
do
anything?
- **U.S. Proposals for Kyoto:**
 - *Legally-binding targets and timetables*
 - *Flexibility: trading among nations*
 - *Inclusion of developing nations (though no targets).*

Stabilizing emissions won't stop global warming. CO₂ concentrations would continue to rise.

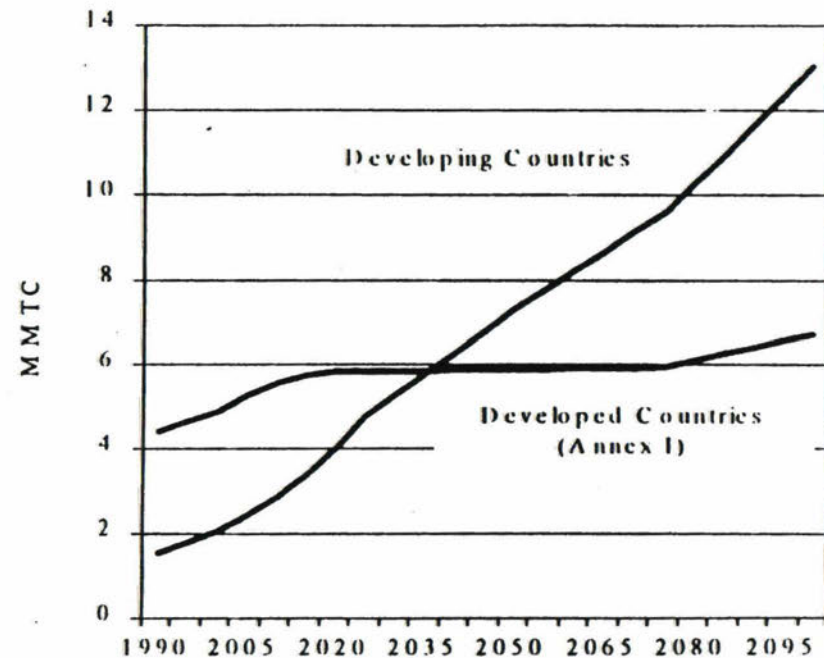
- To stabilize concentrations, emissions must eventually drop well below current levels.
- Issue is *timing*
 - Deferring reductions lowers costs by allowing normal retirement of old capital and time to finish further projects;
 - *But* early action enhances credibility with other nations
- A least-cost path to stabilize concentrations at twice pre-industrial levels would allow emissions to rise now, fall to 50% of 1990 later.



... what? ...
critical assumptions?

Both developed *and* developing nations are critical.

- Emissions growing much more rapidly in developing countries, primarily due to population growth.
- **Developing nations will account for more than half of all emissions by 2035.**
- *But* developed countries may have to act first to establish credibility.
- Developing nations thus far unwilling to commit to specific emissions targets.



Issues for Decision

- **What targets/timetables should be proposed internationally?**
- **When?**
- **Must agreement be tied to:**
 - **Future action by developing nations?**
 - **Emissions trading rights** among developed nations?
 - **“Joint implementation”** purchase of rights from developing nations?
- **What steps can/should be taken domestically? When?**
 - Emissions regulation (tradable licenses)
 - Transition assistance for coal industry, workers, et al.
 - More funding of R&D

Targets & Timetables

- **Rio (voluntary): 1990 levels by 2000**
- **Possible Kyoto Approaches**
 - **Cut below 1990 levels by 2010 (EU: 85%-90%)**
 - **Stabilize at 1990 levels by 2010, cut further later**
 - **Stabilize by 2020, cut further later**

Domestic Economic Effects of Stabilization to 1990 Levels by 2010

- Would be achieved largely by shifting from coal to natural gas. Could cut coal consumption by a third.
- Increase in electricity costs perhaps 16% on average, twice that in Northeast.
- Employment losses in coal mining, especially in the East
- If applied to petroleum, equivalent to about 25¢ per gallon.
- Could reduce GDP perhaps 0.5% to 1.0 % if the policy were implemented efficiently, could be 2% or more otherwise.
 - *Economic effects offset if emissions licenses were auctioned, and revenues used to cut marginal tax rates on business.*
 - *If international trading permitted, then domestic dislocations would be smaller, but international cash flows could be large.*

US Implementation of Emissions Limits

All approaches problematic

- “Cap and trade” of emissions rights cuts emissions at least cost, but requires decisions about whether to auction permits or allocate them to current users.
- “Emissions Trading” with other developed countries could reduce costs substantially, but would involve transfer of billions of \$ to Russia and other transition economies now, and set a precedent for even larger transfers to China, India and other developed countries in the future.
- “Joint implementation” if ever agreed could involve large cash transfers to developing countries even before they commit to limits of their own. Would also need ways to police emissions in LDCs.
- Some economists propose “carbon tax.” Administration has opposed.

Alternatives to Emissions Targets

- Some nations have proposed common *control policies*, rather than common *emissions targets*.
- Administration has opposed consideration of internationally coordinated emissions policies, due to concerns about, e.g.:
 - carbon or other taxes,
 - coordinated efficiency “standards” (e.g., auto CAFE standards, appliances).
- Some economists argue strongly that the emissions cap & trade approach cannot be policed and will involve unacceptably large cash transfers; that some set of coordinated policies has a better chance of success.

Budgetary Issues: R&D Funding

- Climate Change Action Plan includes over 40 “actions” to spur energy conservation by promoting existing, cost-effective technologies.
 - Examples include use of “green” (fluorescent) lights, energy-efficient new-home construction, parking “cashout,” etc.
- CCAP has been funded below Administration proposals (\$505 million over FY 1995 to FY 1997 v. administration request of \$985 million).
- Proponents claim that CCAP will dramatically reduce fossil energy use. This is unlikely.
- R&D and technology transfer efforts are an alternative means of encouraging international action.

Timing Issues

- **1997: G7 in June; Kyoto negotiations in fall**
- **If agreement in Kyoto**
 - **Treaty ratification**
 - **Negotiation of implementation agreements (e.g., emissions trading, compliance)**
 - **Congressional approval of both treaty and implementing legislation**

early 2... when a young chief is killed, another springs up to take his place. One leading commander, Djamel Zitouni, is said to have been killed in the fighting at Ain Defia—150 kilometres (95 miles) south-west of Algiers—last month. The army has not yet given its version of that battle, which lasted about ten days and was on a scale not previously seen in Algeria's three years of near-war. One account says that the GIA was holding a conference at Ain Defia when the army, given a tip-off, swooped, killing hundreds of rebels. Other reports talk of an army mutiny. All that is certain is that a lot of people are dead.

Climate change Smoke

BERLIN

HYPOCRISY is nothing new in international politics. But when the topic is global warming, the ability of governments to say one thing and do another is, let's say, breath-taking. As the Berlin climate-change summiters waffled on this week, official delegations held countless press conferences proclaiming how worried their governments were that the accumulation of greenhouse gases could lead to catastrophe. At countless closed meetings, each country then refused to do anything much about it.

With carbon-based fuels supplying 90% of world energy, governments have good reason to delay dramatic efforts to cut the output of carbon dioxide. "It would play havoc with our economy," said an Indian diplomat. But rather than openly debate the costs, most countries chose instead to make wild demands that others bear them.

Rich countries are committed to stabilising their greenhouse output by 2000 at 1990 levels. Before going any further, said many of the rich—notably the United States—they wanted poor countries (which are now committed to nothing at all) to show some willingness too. The poor said No. They do not want to hold back their economic growth to solve a problem which they—so far—have not done much to cause. Instead they called for grand new commitments from the rich: a 60% cut in output over the next 30 years was one idea.



By Thursday the world's environment ministers were still haggling. At best the summit looked likely to notch up a meagre achievement: an agreement to start negotiating a new set of targets. Green lobbyists glumly admitted they must now look ahead to future summits.

For them, and for many developing countries, the villain of Berlin was the "carbon club", the term they use to describe the oil and coal lobby. The American delegation, complained one Asian diplomat, was being lobbied by "very sinister mafiosi". Certainly OPEC countries did their best to obstruct negotiations.

Yet Berlin also saw the emergence of strong business pressure in favour of curbing greenhouse gases. "There is a powerful lobby on the other side," pointed out one Latin American diplomat. "And it's very, very effective". Insurance firms, for example, came to Berlin to give warning that they could be bankrupted if global warming led to a string of natural disasters.

Renewable-energy firms also stand to win from regulations on greenhouse gases. The conference centre was dotted with stands demonstrating solar energy, gas power plants and even the use of vegetable oils to run engines. The Business Council for a Sustainable Energy Future, an American lobby group demanding tough action on climate change, launched a European off-shoot at the conference. Even some oil companies are divided about which side to take on the climate debate: new targets would hurt their oil business, but could boost demand for natural gas.

Even this encouragement for the greens has its smoky lining. Most non-polluting energy sources still cost more than carbon fuels. Don't wait for governments to offer to subsidise the difference.

Venezuela

Cockroach king

CARACAS

RAFEL CALDERA, Venezuela's president, has a good record as a democrat. He helped to found Copei, one of the two big parties that alternated in power for more than three decades, and became the country's president. When scandals, corruption and failed coups had discredited the established parties, he resurfaced in 1993, still spry at the age of 77, as one of the few politicians whose integrity was not questioned. He built a coalition of small parties known as *chiriperos*, cockroaches, which propelled him into office again.

He has been doing some undemocratic things of late, however. Soon after he took office early last year, Mr Caldera suspended economic freedoms enshrined in the con-



Caldera: a record unrivaled

stitution—"temporarily", he said, to set the economy right. He then began a crackdown on "hoarders and speculators". When Congress in July voted to restore most of these rights, he overruled it. Critics of his government, from left and right, have had late-night visits from security men to discuss activities that "destabilise democracy". Now the opposition parties are again calling for a restoration of civil freedoms—and again they are getting nowhere.

One victim of this attitude has been the press. There is no explicit censorship. But journalists complain of "a climate of fear" in which they are afraid to publish direct criticism of Mr Caldera. Instead, they more often publish critical headlines, but cite someone else as the source, from foreign newspapers to obscure research reports.

President Caldera holds all the cards. For a start he is widely popular. The suspension of constitutional rights gives the government broad powers to search and seize assets. Foreign-exchange controls mean it can limit purchases of newsprint (all imported), equipment and spare parts. On top, it recently toughened the requirements for qualification as a journalist—and the penalties for working as a reporter without the right credentials are severe.

Why does Mr Caldera do it? He has taken to calling his critics traitors, and claims there is a conspiracy among foreign investors, foreign journalists and once-powerful Venezuelans to bring his government down. The country has in fact faced two attempted coups in recent years. Yet Hugo Chavez, the army officer behind them, is out of jail—thanks to an amnesty granted by Mr Caldera—and busy fomenting more trouble. Perhaps the pen really is more to be feared than the submachinegun.

Global warming and cooling enthusiasm

BERLIN

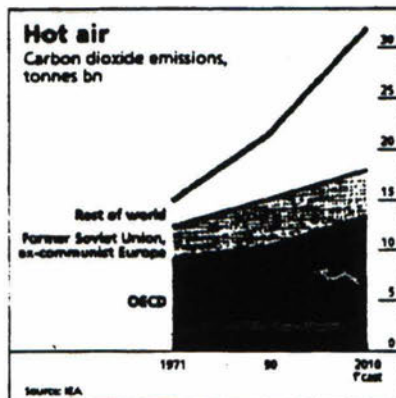
HAS the great global-warming bubble burst? The 1992 "Earth summit" in Rio, at which the world committed itself to avoid the threat that is said to overhang it, was conducted in a spirit of zeal. The globe had just experienced some of the warmest years on record. In many countries voters were flush with green idealism. Politicians made eager promises about curbing greenhouse gases. This week, as politicians, bureaucrats and the ever-growing fringe of non-governmental organisations gathered in Berlin for the second summit on climate change, reality sent a chill breeze through their deliberations.

Talks on the global climate are now viscous with regional politics and national self-interest. For all its output of warm guff, the conference was expected, at best, to thaw out only a few of the problems. Too much is at stake, and quite different things for different countries. Broadly, these:

- **Small island states.** The threat of global warming terrifies a group of 30 Caribbean, Indian Ocean and Pacific islands. They fear it would lead to a rising sea level that would flood low-lying areas, and might overwhelm some of them, such as the Maldives, altogether. This group wants the rich countries to promise to reduce their carbon-dioxide emissions by at least 20% from 1990 levels by 2005. Fat chance. The rich countries promised at Rio to stabilise at the 1990 level by 2000. Most are unlikely to achieve even that.

- **OPEC.** This is the group most vehemently opposed to action on climate change. The economies of many OPEC countries have already been badly hit by low oil prices. If their industrialised customers commit themselves to further reductions in greenhouse-gas emissions, demand for oil and gas will fall. Green groups suspect that Saudi Arabia ratified the Rio treaty only in order to disrupt negotiations. "Whatever's on the table, they say no," says one diplomat.

- **Rich countries.** Although industrialised countries still have five years left to meet their target of sta-



bilising emissions, the omens are poor. Voters are more concerned about jobs than the environment. So governments have taken few costly measures. America, Canada, and the European Union (EU) admit that, on current trends, they will not reach their targets.

At Rio, the EU was the world's most forceful advocate of strong targets. Since then sundry proposed EU policies to reduce emissions—a carbon tax, for instance—have been pigeon-holed. Those EU countries likely to meet their targets, such as Britain

and Germany, will probably do so by accident. Unification has killed off antique coal-burning industries in eastern Germany. Britain has shut most of its coal mines to save taxpayers' money, not the world's environment.

Unable to keep their promises, rich countries have reacted in three ways. First, they have squabbled over definitions. For example, should countries be allowed to meet their targets by, say, planting forests, which would absorb carbon dioxide? The United States, with plenty of space to do it in, says yes. So does New Zealand. More crowded countries disagree. Some countries have adjusted their targets, arguing that 1990 was an unusual year. Others want to exclude emissions from certain sources, for instance aircraft fuel.

Second, many rich countries have pushed the idea of "joint implementation". This would allow them to pay for emission-reducing projects in poor countries—pollution control or indeed tree-planting, say—and then to count the reductions against their own targets. This would save them money: the marginal cost of reducing emissions in poor countries is low. But many—not all—poor countries oppose the idea, arguing that would merely allow rich countries to avoid tough action at home.

Third, and most important, rich countries have begun to ask why they should make any effort against global warming when poor ones have committed themselves to nothing. Indeed, by 2010, carbon-dioxide emissions from developing countries will probably be more than the rich

world's output. Fifty years hence, coal-burning by economic giants such as China and India could make today's rich world emissions look insignificant.

- **Poor countries.** The mere suggestion that the third world should make any commitments is a "diplomatic dead end", says one green activist. It argues that the rich have contributed most to greenhouse-gas emissions so far, and should therefore suffer the most pain. "We take global warming seriously", says one Asian diplomat. "But we are disillusioned by the way it is being handled by the developed world."

However, the poor can smell money in the climate-change negotiations. If the rich world wants them to reduce emissions, they argue, let it both pay the cost and provide them with non-polluting



technologies. "We are talking about a huge, huge transfer of resources," says one Latin American climate-negotiator. Really? The rich are not. Few are ready to supply new technologies for free. And the Global Environment Fund—the body which distributes money to poor countries—has so far received pledges of only around \$2 billion for 1994-97; enough, maybe, to pay for the poor to find out what they are emitting anyway.

Some poor countries see "joint implementation" as a way to draw in rich-world investment. Chile, Costa Rica and Pakistan have all signed agreements with the United States. Others are playing hard to get. An Asian diplomat reckons that his country will earn a higher price for this sort of project if it delays agreement until 1999. By that time, he reasons, rich countries will be desperate for ways to fulfil their Rio targets. Possibly; but in collaboration with whom? Those whose claim to take a threat seriously does not include doing anything about it?

South Africa

Fighting Winnie

JOHANNESBURG

IS SHE finished? Or on the way to the top? Winnie Mandela certainly felt her dismissal from the cabinet on March 27th as a personal blow. But the loss of her post as deputy minister of culture, science and technology, for defying President Nelson Mandela and criticising the government of which she was part, does not end her long political career. It may help her.

In her nine months of office, Mrs Mandela more than once accused the gov-

ernment and fellow African National Congress (ANC) members of being less concerned to assuage black grievances than white anxieties. She attacked their eagerness to make a deal with the white establishment and to "sleep between silk sheets". She herself, her critics remark, indulges a taste for fine clothes and expensive cars. But that does not seem to diminish her popularity with the black electorate. And now she can freely make her populist rhetoric the focus of a campaign.

At the ANC's national conference in December, she came fifth in the vote for the executive, after the election of key office holders including Mr Mandela himself and his deputy—in the party as in the nation—Thabo Mbeki. Other populists too did well. Bantu Holomisa, formerly military ruler of Transkei, topped the poll; Peter Mokaba, past president of the ANC Youth League, came third; Harry Gwala, a fiery Stalinist from Natal, ninth. If the populists hold together, they could create grave difficulties for the present ANC leadership.

Mrs Mandela has always been a fighter, against white rule in the past, recently against her foes—the "cabal" as she labels them—within the ANC. By late 1992 she appeared to have lost. She had been found guilty in 1991 of involvement in the kidnapping of a black youth later murdered by one of her bodyguards. Mr Mandela in April 1992 announced that he and his wife were to separate. She resigned as head of the ANC social-welfare department and, in September 1992 was pushed from all her ANC positions, after the publication of a love letter reportedly written to her by her dashing young number two in the department. Yet by December 1993 she was back, elected to the presidency of the ANC Women's League,

a victory that guaranteed her a seat in parliament and a post in the future elected government.

Can she now stage another spectacular recovery and re-emerge as a serious contender for the presidency after Mr Mandela, who is now 76, is gone? Some think so. Yet her main potential is probably as a backer—or wrecker—not a candidate. For there is a new, perhaps decisive, factor in the calculation. In the past, Mr Mandela has either stood by his wife (during the crisis over the kidnapping) or remained publicly neutral (after their separation). Now he has disowned her politically. She cannot claim that her only critics are the "cabal".

The ANC and its allies—the Communist Party, the Congress of South African Trade Unions and the South African National Civic Organisation—have rallied around Mr Mandela, promising "unequivocal support". Even the ANC Women's League has acknowledged his right to dismiss his estranged wife. With these forces against her, Mrs Mandela may find her position in parliament threatened if she persistently challenges the ANC leadership. Members are elected from a party list. If the leadership dislikes them, down or off the list they go.

Meanwhile the police are looking into allegations that Mrs Mandela used her cabinet job to aid a building company, in return for kickbacks. A Supreme Court judge last week ruled that the search warrant used by policemen when they raided her house was invalid, but the investigation continues.

So she looks an unlikely successor to Mr Mandela. But she could certainly help or hinder likelier hopefuls. The front-runner today is Mr Mbeki. He rose with the backing of the populists. Will they now turn against him, for his role as Mr Mandela's trouble-shooter in the run-up to Mrs Mandela's dismissal? If so, the balance could tip toward the ANC secretary-general, Cyril Ramaphosa, for all that Mrs Mandela used to call him a member of the cabal.



Never underestimate her

Rwandan refugees

Crime and nourishment

GOMA, Zaire

THE Mugunga camp in Goma, near to the border with Rwanda, supposedly is a refuge for people, nearly all of them Hutus, who fled that country last summer and dare not go home, now that it is run by Tutsis. In reality, the camp looks more like a military training ground. Soldiers from the army of Rwanda's former Hutu government loiter about in full uniform. Militiamen wave axes menacingly at white-skinned foreigners. Weapons are hidden close by and vehi-

THE ECONOMIST APRIL 15T 1995

Stay cool

ENVIRONMENTALISTS are dismayed. Their efforts to scare the world over global warming seem not to have worked. Three years ago, in Rio, governments agreed to hold down their output of "greenhouse" gases, such as carbon dioxide, that are thought to be raising the earth's average temperature. But when this week's Berlin conference (see page 33) asks what progress has been made since Rio, the answer will be: virtually none. Rich countries are unlikely to meet the Rio target of reducing output of greenhouse gases to 1990 levels by 2000.

Even if they do, growing emissions from coal-burning poor countries will more than offset their success. Few poor countries are even considering restraining their output of greenhouse gases. And thus, say the greens, will a short-sighted world stroll insouciantly towards a calamitous future of storms, floods and drought.

Well, maybe. It would certainly be a pity if the world's governments retreated from the promises made at Rio, for that would bode ill for any attempts to deal collectively with global environmental problems. Nonetheless, penguins and people can afford to relax for many years yet. For all the green clamour, it is far too early to be panicked into Draconian actions to avert global warming: especially when most actions would pose a bigger threat to human wellbeing than does global warming.

Two clouds, and a hot prediction

Consider, first, the uncertainty of scientists about the extent of global warming. Despite recent advances (see pages 65-67), science still understands little about the world's climate, a system that depends on a huge range of variables, with causation flowing in every direction. Most scientists agree that, provided other variables remain the same, big increases in carbon dioxide will boost temperatures. But the extent of the boost is widely disputed. And nobody can predict whether other variables will remain the same. Some scientists reckon that rather than just growing gradually warmer, the climate may become subject to sudden lurches. That makes it even harder for countries to prepare for climate change. The Intergovernmental Panel on Climate Change, the body of scientists studying global warming, reckons that a doubling of carbon in the atmosphere could lead to a temperature rise of anywhere between 1.5°C and 4.5°C.

There is also much uncertainty about the costs of global warming. Some areas of the world would benefit from a warmer climate. Cold wastelands, for example, might become fertile farmland. Other areas would suffer. If global warming raised the sea level, valuable inhabited land (eg, in Bangladesh, the Nile delta and the Maldives Islands) would be submerged. Estimates of the overall economic impact of global warming depend on weighing these costs—the dislocations of ways of



life based on the present climate—against potential benefits, ie, the opportunities for growth in places where the climate improves. Few expect the benefits to carry the day, especially if the temperature rises quickly.

Economists have, however, pointed out that even substantial net costs can and should be tolerated if the alternatives are worse. Even a pessimistic prediction that climate change could knock 20% off world income in a hundred years' time would imply merely that the world economy expands a little more slowly

than otherwise. To set this in perspective, consider another extrapolation: the world economy could, if recent growth continues, be over 300% bigger in 2095 than today—and so that much better able to bear the costs of coping with climate change.

One of the few certainties about global warming is that the costs of severely curbing emissions of greenhouse gases now would be huge. The world relies on carbon-based fuels for 90% of its energy needs. A quick, enforced switch to non-polluting alternatives would savagely cut people's living standards. In developing countries reliant on fossil-fuelled economic growth to lift them out of poverty, the pain would be acute. Why should people make such a sacrifice for a problem whose extent and cost are so uncertain? There are more pressing environmental concerns such as urban smog, the spread of disease and inadequate sanitation in poor countries. Unlike global warming, these cause enormous suffering for millions of people now. And it would cost less to alleviate or even eliminate them than to reduce sharply the world's output of greenhouse gases.

This does not mean that world governments should do nothing about the possibility, however remote, of climatic catastrophe. Many policies that would reduce greenhouse emissions are desirable on their own terms. For example, most state subsidies for energy industries should be scrapped on grounds of economic efficiency. That would lead to less coal being burned (the coal industry is often heavily subsidised) and to higher electricity prices, encouraging conservation. Proper road pricing should be introduced to reduce congestion in cities. Policies designed to deal with one environmental problem may not necessarily help with others, however. Scrubbing sulphur dioxide out of power-station emissions curtails acid rain, but it may enhance warming; sulphur compounds in the atmosphere cool the earth.

Besides encouraging energy efficiency, governments should also continue to finance research into the science of climate change, and into how to reduce the costs of non-polluting fuels. Such actions could pay dividends if more drastic measures to counter global warming ever became necessary. Even the occasional jamboree such as Berlin's may be justified, so long as it does not foster panic: the wheels of global co-opera-

tion should be kept oiled in case climate change turns nasty. Other than that, however, patience should be the watchword. Within a couple of decades, scientists should have a firmer grip on the influences on climate. By then the costs of altering the world's economic structure are likely to be lower: although prices of most non-polluting fuels, such as solar power, are still higher than fossil fuels, the gap is narrowing. And if climate change turned out to mean no more than a slow but steady rise in temperatures, the costs of adapting as warming occurs (such

as building higher sea walls) might still prove lower than the costs of prevention.

Greens will no doubt continue to paint their scary pictures of the future. What, they will ask, if climate change were to entail a sudden lurch that led to half the world starving to death in 50 years' time? The best answer is that anything can happen in half a century: even an invasion by aliens, say. On present evidence, though, any huge catastrophe looks highly improbable. There is still time to bask in the sun.

Candidate Chirac

Has he changed enough to become the next president of France?

LIKE the sumo wrestlers he admires, Jacques Chirac, would-be president of France, is a master of tactics, timing and deadly bursts of speed. Dismissed as a has-been, for months Mr Chirac trailed in the opinion polls. Now, with less than a month to go before voting starts for the presidency, he has sprung back as the contender to beat. By presenting himself as a man of deep experience yet with the common touch, he has made the Socialist candidate, Lionel Jospin, seem merely dull and the prime minister, Edouard Balladur, look like a nose-in-the-air bourgeois. Candidate Chirac is on the rebound. But would he make a good president?

One issue was bound to dominate the election: unemployment, which has stuck at over 12% for more than a year (see page 42). Mr Chirac's solution is a radical expansion of employment subsidies, sharp cuts in payroll taxes and increased spending on education and health. He cannot keep these promises, while also reducing the public-sector deficit, as he says he will, from 5.7% of GDP to below 3%, without increasing taxes sharply. But Mr Chirac has promised to cut taxes. To the charge of innumeracy can be added that of sogginess: he wants to give still more protection to France's farmers.

Mr Chirac's numbers may not add up, but nor do those of his opponents. Especially when it comes to the battle for the presidency, the French take politicians' promises for what they mostly are—hot air—and concentrate instead on the personal qualities of the candidates.

Mr Chirac's claim to be a man of experience is borne out by his record of office. He first became a minister almost 30 years ago. He was prime minister twice, in 1974-76 and then in 1986-88 (though without notable success). He has been an effective and admired mayor of Paris for almost 20 years. Though he has tried twice before for the presidency, in 1981 and 1988, and lost, this is now presented as necessary preparation: like François Mitterrand, and De Gaulle before that, Mr Chirac has endured a long "crossing of the desert" in mid-career.

His famous resilience, however, is not matched by consistency. Once known as a nationalist Eurosceptic, a point he was happy to highlight last year when he thought Jacques Delors would bid for the presidency, Mr Chirac now presents himself as a good European and a supporter of a single currency. Once a right-wing budget-slasher who abolished the wealth tax in 1986 (and before that a proponent of trade unions and workers' rights), he has reinvented himself once again, this time as a one-nation Gaullist with a social conscience. The real Chirac, say

his supporters, is these days a more mature, sober politician. To his detractors, Mr Chirac is erratic and impulsive, a man who will jump at the first idea thrown at him.

The great unanswerable question is whether such a compulsive tactician could make a good president. Yet Mr Chirac's policy zigzags over the years have been no worse than those of President Mitterrand. Since Mr Mitterrand's most spectacular U-turn, in 1983, when he junked his reflation convictions for the austerity and stable-franc policies that have prevailed since, he has been a pillar of stability. The moral constraints of the presidency—the incumbent is, after all, president of all of France, not just of one of its political factions—would restrict his freedom to wobble.

But President Chirac would also have the advantage of a large centre-right majority in parliament. How might he use it? He is not a radical in the modern British or American sense. He is a *Radical* in the historical French one—a man of the centre, of toleration and modernisation. Although he has taken a tough line on immigration, more than most leading conservatives he has kept his distance from Jean-Marie Le Pen's xenophobic National Front. Sceptical about the sort of European political union favoured by some German conservatives, Mr Chirac nonetheless campaigned for the Maastricht treaty in the 1992 referendum, though many of his allies opposed it.

Stand up, and be counted

Mr Chirac is far from a shoo-in for president (if only because many voters have yet to make up their minds). Yet his constant campaign theme—France's need to "break with the past"—has touched a chord among the electorate. France faces big challenges. At home, the welfare state, the social-security system and the public-health and education systems are all in urgent need of reform. Meanwhile Germany, the country against which France measures itself, has grown larger and more powerful. The relationship with Germany needs to be recalibrated—a tough task at the best of times, but one that will become trickier still if European monetary union turns out to have the political consequences that many French politicians, including Mr Chirac, hope to avoid.

This is the first opportunity French voters have had to choose a president to meet these new challenges. Mr Chirac's bid to be that president seems a strong one—always assuming that the real Jacques Chirac has finally stood up.



safe, and could provoke an immune response that may be helpful. The Immune Response Corporation of Carlsbad, California, a company named after its aim, has tried similar experiments. Though it has done no human trials on MS vaccines, it is beginning some on rheumatoid-arthritis vaccines, aiming at the relevant TCR components. Dr Marrack is interested in a similar approach, based on her superantigen work.

Howard Weiner, David Hafler and their colleagues at the Harvard Medical School, and a company called Autoimmune Inc are looking at a different way of disciplining the unruly immune system. Starting from the long-established fact that people tend not to mount immune responses against the food they eat, they have been feeding myelin to MS patients in the hope that it will act as a sort of anti-vaccination, cancelling out an existing immune response. The idea is that the suppression mechanism that works through the gut and stops responses to food will, if myelin is seen as a food, stop responses to myelin. In last week's *Science* they published results showing that some of

the patients eating myelin did indeed show some suppressive effects.

At the moment there are far more questions than clinical answers. Of course, it may not be necessary to solve all the mysteries of the immune system, or to manipulate it in precise and detailed ways, to get the desired effect. One of the cytokine therapies, such as beta interferon, which has been put through a large trial among MS patients, may turn out to do the trick. But improvements in knowledge and technology are making more detailed manipulations easier to envisage, and the high rewards for success make the fuss involved seem worthwhile. According to Brandon Fradd, of Montgomery Securities in San Francisco, the American market for MS and rheumatoid-arthritis treatments is worth billions of dollars. And if ways can be found to restore discipline to the immune system, perhaps its new commanders can also find strategies that will help it vanquish enemies that at present can outsmart it—such as chronic infectious diseases and cancers.

Global warming

Cool costing

NOBODY is sure how far and how fast the earth will warm up as carbon dioxide (CO₂) and other gases build up in the atmosphere. But that did not stop governments from signing a treaty last year to try to reduce the growth of such gases, nor economists from estimating the cost of the policies that the treaty may imply. Most economists have looked at the economy of the United States, and extrapolated from that. But the OECD has a model which does better, and the findings so far are summarised in its latest *Economic Studies*.

The model has two special features. It can look in some detail at individual regions, such as China, India or the EC, and at the trade flows between these regions. That allows it a unique view of how different policies would affect international competitiveness. It can also look at the ways energy prices are distorted by taxes and subsidies.

Some of the findings should cheer the officials who hope to turn last year's climate treaty into something workable. For instance, the OECD thinks that the cost of stabilising the global output of CO₂ at 1990 levels by 2050 would be between 1% and 3% of world GDP. That (to pessimists) means forgoing the entire output of Canada today; but (for optimists) it is only one year's world economic growth.

Setting aside the question of whether such a cost would buy commensurate benefits (which the OECD has not yet tried to answer), any agreement should aim to be as cost-effective as possible. That implies reducing CO₂ output in the countries where it is cheapest to do so, rather than sharing cuts equally across the board.

The most cost-effective places to make cuts turn out to be the coal-producing developing countries, which means mainly China and India. The alternative—brave gestures by the rich countries to reduce their own CO₂ output—will have little effect on the global total, because of the rate at which energy use by the non-OECD countries is likely to grow (see chart on next page).

The way a carbon-cutting agreement is designed will determine which countries carry most of the cost. But, as the OECD shows, no agreement will work unless the countries that are likely to cut least (the OECD nations) are willing to make large payments to compensate those that cut most (the big third-world energy producers).

The most heartening finding of the OECD's work is how much the growth of CO₂ output could be cut without making any country worse off. This is largely due to the amount of subsidy slopping around in the system. Domestic energy prices in many countries outside the OECD have been

Backing off

DETROIT

WHEN car designers gather together, as they recently did at the annual shindig of the Society of Automotive Engineers in Detroit, they no longer talk only of pistons and camshafts. Today's designer is as comfortable with microelectronics as mechanics, and is looking to apply his learning—by making cars cleverer, and maybe doing the same for the roads beneath their wheels.

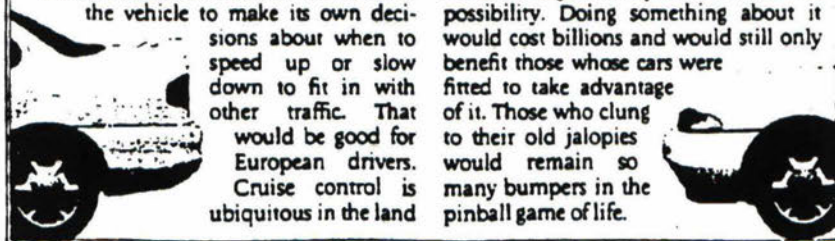
Latest among the car-smarteners is a joint venture between the Eaton Corporation, a components company based in Cleveland, Ohio, and VORAD Safety Systems of San Diego, California. VORAD's Vehicle Onboard Radar gives the driver a sixth sense. It sweeps the road with radar and monitors the speed and distance of surrounding vehicles. If it thinks a collision is imminent, it screams what may be a life-saving warning. This has been enough to impress Greyhound Bus Lines—the company is installing VORAD on its fleet of 2,400 vehicles.

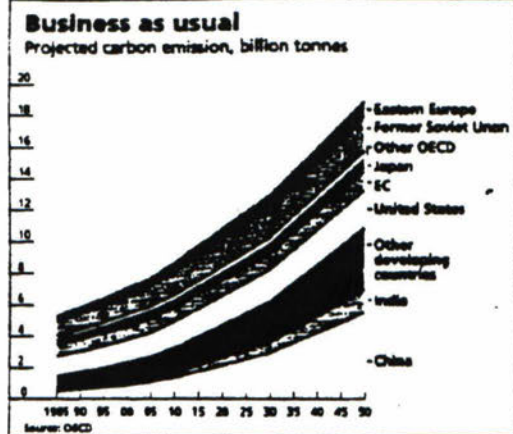
Soon, the system could be hooked up to a car's cruise control. This would allow the vehicle to make its own decisions about when to speed up or slow down to fit in with other traffic. That would be good for European drivers. Cruise control is ubiquitous in the land

of the freeway, but it is unpopular on the crowded roads of the Old World; there is not much point in something you are continually having to override. Self-adjusting cruise control could take much of the Angst out of the Autobahn.

Avoiding the crowds is also the objective of another recent step towards the "smart" road. The TravTek project has installed computers into 100 hire-cars in Orlando, Florida. Punch in a destination and the computer navigator displays the best route—a radio-link to a regional traffic-control centre automatically advises it of traffic snarls and plots a detour.

The one caveat of all this cleverness is cost. Stand-alone systems like VORAD are relatively cheap—Greyhound is paying \$2,000 apiece for its electronic eyes. Eaton reckons that in time that might fall to \$350, suitable for private cars. But TravTek relies on collecting and distributing a lot of data—a big fixed cost. Even thinking about clever highways is proving expensive—in 1991, Congress voted a \$660m budget merely to look into the possibility. Doing something about it would cost billions and would still only benefit those whose cars were fitted to take advantage of it. Those who clung to their old jalopies would remain so many bumpers in the pinball game of life.





hugely subsidised. Energy subsidies, net of taxes, cost the world \$235 billion in 1985. The effect is to underwrite CO₂ output. In non-OECD countries, the implicit carbon subsidy worked out at \$90 a tonne in 1985,

especially in the former Soviet Union. Energy use, and particularly coal, does plenty of much less controversial environmental harm. And energy subsidies do uncontroversial economic damage.

Breast cancer

Forewarned is what, exactly?

BETHESDA, MARYLAND

WHEN they reach 40, American women are told that if they have regular mammograms, they will be less likely to die from breast cancer. In most other countries, this advice is given to women only at the age of 50. Does starting the x-ray examinations later hurt the women in those countries? Or are American women getting overzealous and poor advice?

The American Cancer Society, the American College of Radiology and the government's National Cancer Institute (NCI) have long insisted that the American approach is correct. Their guidelines are promoted so thoroughly that an American woman in her 40s who ignores them is made to feel she is endangering her health needlessly. But the evidence presented at an international meeting hosted by NCI in late February was by no means so compelling.

Six trials from around the world were reviewed at the meeting; in each, one group of women was regularly screened with mammography and, for comparison purposes, a control group was not. In these trials, in which 500,000 women took part, the only people who clearly benefited from the examinations were those who were 50 or older when they began to have mammograms. Over a decade of study, these women had a significantly lower chance of death from breast cancer than their unexamined contemporaries. So it would seem there is no harm in waiting until a woman's 40s are behind her before starting mammography. In fact, in almost every study, breast-cancer

death rates were slightly higher for women screened during their 40s than for their unscreened counterparts. The effect was small enough to have occurred by chance, but it has turned up so consistently that researchers are not sure.

Mammography for younger women does have its defenders. Daniel Kopans, a radiologist at the Massachusetts General Hospital, attacked all the studies. He said that in each of them either the mammography was poorly done, or the test subjects

the equivalent of \$10 a barrel of oil. Removing those subsidies will make their economies work more efficiently—and reduce their output of global-warming gas.

What if global warming turns out to be less sinister than most scientists now think, or if last year's convention is stillborn? Will all this high-powered economics be no more than intellectual callisthenics? The work on energy subsidies will still be useful. Indeed, it has already helped to transform the World Bank's approach to energy use in developing countries and

were improperly selected, or both. Besides, he maintained, the technology is constantly improving, making all past studies irrelevant. On this basis, people should keep studying until they find the effect that Dr Kopans believes to be real.

Few at the meeting endorsed the view of Dr Kopans that the value of mammography for younger women should be taken on faith. Suzanne Fletcher of the American College of Physicians, who chaired the meeting, summed up with the prevailing feeling: "There is no reduction in breast-cancer mortality" in the studies of women in their 40s who have been followed for five to seven years. The reduction seen in the few studies that have followed such women for longer is "at best marginal." In fact, only one study showed such a reduction: the benefit, which was slight, took 18 years to become apparent.

Dr Fletcher, with four others who were at the meeting, will convey its findings to President Clinton's National Cancer Advisory Board when it meets in Miami later this month. What will happen next is uncertain; the more so because the American Cancer Society, which carries enormous weight with the public, has decided to stick with its current screening recommendations.

Nonetheless, the potential savings in changing the age for routine mammography are significant enough to make it appealing: about \$550m a year for the x-ray examinations alone. More costs accrue when the results are suspicious, prompting further tests and raising the total cost to roughly \$1 billion a year. If this were helping, that would be reasonable; but the evidence is that it does not lead to anyone living longer. In terms of results, mammography for the 40-somethings remains a triumph of hope over experience.

The complications

WHY doesn't mammography work as well for younger women as for older ones? One answer is that younger women have denser, less fatty breasts. This higher density makes the x-ray films harder to read. Cancers are harder to pick up; benign lumps harder to tell from cancerous ones.

Even if mammograms did work on the under-50s, would they do any good? Some scientists think not. A Canadian study of 50,000 women, published last year, showed that although mammography could certainly identify cancers smaller than those found through careful physical examination, there was no evidence that this made any difference to survival rates. Indeed, several studies

suggest that testing leads to over-diagnosis because it finds tumours that would never be life-threatening.

There is also a chance that mammography in younger women may hasten progress of the disease, either because of the way the breasts are compressed during the examination, which might encourage the spread of cells from a small pre-existing tumour, or because the powerful treatments used after early detection might do more harm than good. A further worry is that even at today's low doses, the repeated x-rays may do a little harm. All these ideas are purely theoretical. But it is known that both the biology of breast cancer, and its response to treatment, do differ with age.

THE ENVIRONMENT

Whose world is it, anyway?

NATURE is no respecter of national boundaries. Across those dotted lines on the globe, winds blow, rivers flow and migrating species walk or fly. The dotted lines may carve up the earth, but the sea and the atmosphere remain open to all, to cherish or plunder. When people in one country harm that bit of the environment they assume to be theirs, many others may suffer, too. But how, and how much, can countries make their neighbours change their ways? That is the theme of this survey.

Such problems pose new issues for diplomats and economists. Reaching agreement often means resolving conflicting goals and priorities. Even among countries of similar wealth, environmental goals may differ: think of the rows with Iceland and Japan over whaling, or the reluctance of Britain to curb sulphur dioxide from power stations. But cross-border arguments are harder to resolve when many countries are involved, and especially when those countries have widely differing living standards and environmental priorities. Particularly intractable are the two main subjects on the agenda at next month's meeting of the United Nations Commission on Environment and Development (UNCED) in Rio de Janeiro: biological diversity and climate change.

That countries have different environmental goals is not surprising: a policy that brings large benefits to one country at little cost may have the opposite effect on another. But from such differences, many problems arise. Trade is inextricably affected. Tough green standards for products may

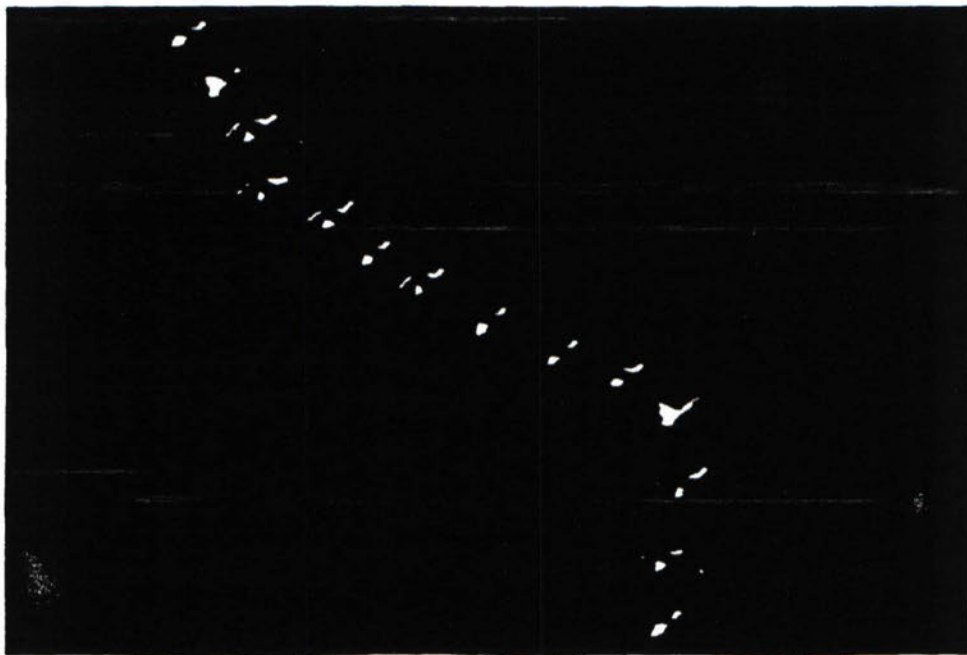
keep out goods from countries that cannot meet them; tough rules to reduce the environmental impacts of production processes will make some companies less competitive than their rivals in laxer nations. Where such differences influence only the local environment, complaints may be muted. But where they cross borders, or affect the common heritage, environmentalists may demand that all countries meet common goals.

That embroils trade in other ways. Trade may be the mechanism by which environmental damage is perceived to cross borders, as in the case of toxic waste or the export of endangered species. It is also one of the few weapons governments can use to bully others into changing their behaviour. When one country feels that the environmental actions of another are harming its own people, it may see trade as a reasonable way to retaliate. Trade sanctions may also be used to provide some added glue for the fragile structure of international environmental agreements.

One earth

International agreement is the best way to solve environmental problems that transcend national borders. These are of three main kinds. First, neighbouring countries may share part of the environment: a river such as the Rhine or the Jordan, a stretch of water such as the Mediterranean or the Great Lakes. Regional problems—acid rain is one example—fall into this category. Second, some environmental resources, such as the atmosphere,

Environmental issues increasingly affect countries' relations with each other. Rich countries must beware of imposing their own green standards on their poorer neighbours, writes Frances Cairncross



Across borders

THE ECONOMIST MAY 30TH 1992



the oceans and Antarctica, are shared by the whole planet. The build-up of climate-changing greenhouse gases, the thinning of the ozone layer and the killing of whales fall into this group. Lastly, some environmental assets clearly belong to individual countries, but their future may affect others, in either material or (more often) spiritual and emotional ways. The disappearance of coral reefs or elephants may not show up as more than a microscopic blip on gross world product, but it gives people in many countries a sense of loss.

To tackle problems like these, countries increasingly sign treaties. Two multilateral environmental treaties came into force in the United States between 1940 and 1959; ten between 1960 and 1979; 11 in the 1980s alone. Like all international treaties, those on the environment can be enforced only by the governments that abide by them.

The market is unlikely to help. Even in an individual country it will rarely deliver what is best for the environment. The costs to individuals and companies of polluting or pillaging the environment will be lower than the costs their activities impose on the rest of society. National environmental policies therefore need government to step in and ensure that polluters carry the costs they would otherwise dump on their fellow citizens.

Without a world government, no institution can compel international polluters to pay. True, there has been a rapid growth of institutions that aim to set international environmental priorities or persuade governments to reach (and abide by) agreements on environmental goals. But such institutions are no stronger than the governments that set them up. Agreement can therefore be based only on the belief that acting together brings more benefits than acting alone.

That belief will frequently be true. If one of the countries living round a polluted lake tries to clean the water by acting alone, it may make heroic efforts but achieve little. If all act together, modest steps may achieve much. If, say, Norway stopped all output of carbon dioxide next week, it would take only 46m tonnes out of the atmosphere. The same amount could equally be saved if every country in the world cut its output of carbon dioxide by 0.22%.

Conversely, if all but one of those lakeside countries reduces the muck it discharges into the water, that one country will still enjoy the improvement in water quality that the actions of its neighbours deliver. An individual country can generally do best of all by dropping out of a pact, as long as it cannot be excluded from the resulting gains. It can thus enjoy the rewards of travelling on the global bus without paying its fare, as a "free rider". This is the central paradox of international environmental agreements. All countries do better by co-operating than by acting alone; but individual countries often have a powerful incentive not to co-operate.

Countries are more likely to succumb to the temptation to hitch a free ride the more the costs of belonging to an international agreement diverge from the benefits it brings; or the longer the gap between the pain and the gain. The balance of costs and benefits will usually vary from one country to another. It will be partly a function of the number of countries involved. If only three countries live around that dirty lake, the gains that each enjoys

from ending pollution will be much larger than if only two clean up. A completely clean lake is much nicer than a two-thirds clean lake. But if a dozen countries are involved, the difference made by the participation of one extra country will be small. The costs of participation to each country are the same, but the gains from co-operating are lower.

How can recalcitrant countries be brought on board? Either the costs of participation can be reduced, or its benefits can be increased. One option is to set targets that reflect the differing costs to individual countries of meeting them. International agreements frequently set uniform goals for each country: output of this gas or catches of that fish must be restricted to such-and-such a level over a set period of years. A well-designed agreement will try to ensure that the largest changes are made by those countries that find them least expensive.

Targets, however distributed, are more likely to be honoured if countries can agree on some way to verify them. That may not be easy. The Verification Technology Information Centre, a London-based body that usually thinks about arms agreements, has argued that it would be harder to reach a climate agreement that does not provide for verification than one that does. In fact, provisions for verification in the initial climate treaty that will be signed next month are even vaguer than the commitments signatories undertake. Verification is essential to build confidence, foster mutual trust, and encourage uncommitted nations to join. Industrial countries are slowly becoming more willing to go a step further and accept international inspection of their performance. The OECD has recently begun an inspection of Germany's environmental policies, as the first step in a programme that will eventually cover all its members.

Another way to reduce the costs of participation is for some governments to bribe others. The countries that gain most from an agreement may reward those for whom the costs are heaviest. The Montreal protocol on ozone-depleting substances (mainly chlorofluorocarbons or CFCs) includes a fund for such payments. Under the new climate treaty, the Global Environment Facility (GEF) will pay developing countries for the extra costs of policies to slow global warming. Such payments are easily (and wrongly) confused with international aid; they are really imports of environmental services. They raise large practical problems. How, for instance, can the world be sure that it is not paying a country to do something it would have done in any case? And how can a country be rewarded for introducing market-based incentives (higher energy prices, for instance), rather than making a one-off investment (in energy-efficient light bulbs, say)?

The problem of punishment

The alternative to bribery is bullying. This may simply take the form of international disapproval. Nobody likes being a pariah. Britain eventually agreed to stop dumping sewage sludge in the North Sea mainly because of the political costs of being dubbed "the dirty man of Europe". America has been under similar pressure to stabilise its output of global-warming gases. A peculiarity of international environmental agreements is the involvement of non-governmental organisations. It is hard

to imagine anti-nuclear campaigners playing a constructive role in disarmament talks, but green lobbyists are active participants in many environmental negotiations. As they are deft at mobilising popular protest, they also play a big part in encouraging governments to keep their promises.

But beyond protest, the options for punishment are few. A handful of examples exist of countries taking on binding commitments. That is likely only if governments are locked together by forces other than the environmental issue at stake. Within the EC, for example, the European Court can oblige a country to implement an environmental directive. Moreover, the Maastricht treaty on European union greatly extends the areas on which environmental policy decisions need only qualified-majority voting rather than unanimity.

Ultimately, trade sanctions are the most tempting weapon. A growing number of agreements include provision for trade sanctions to punish free-riders. The danger is that the costs of such penalties may exceed their benefits: the costs of lost trade may be greater than the environmental gains from wider compliance.

Where polluters are poor and those on the receiving end wealthy, the threat of such sanctions also has unpleasant overtones. The poor—whether they be South American countries destroying their rain forests or East Europeans burning soft coal in their power stations—may feel that their environmental priorities are being dictated by other countries. They may wish to concentrate on environmental risks to the lives and prosperity of their own citizens. They may feel, with some reason, that the rich countries are using their political and commercial muscle to impose their own green agenda.

This survey argues that the rich countries need to be sensitive to charges of "eco-colonialism" if they want to make the world a greener place. They need to be careful about using trade as a weapon to



Blowing the wrong way

get their way and need to explore new kinds of financial transfers and aid. Developing countries that pursue environmental goals which go beyond their national interests can reasonably expect the developed countries to find ways to compensate them for doing so. Only by finding new kinds of bargains and new institutions to strike them can the interest of each country in its neighbour's environment be expressed in ways that do not threaten trade or national sovereignty.



RFF Climate Change Research

RFF launched its Climate Economics and Policy Program last fall to conduct basic and applied research and policy analysis related to global climate change. An initial set of research projects under way includes:

- Bringing Uncertainty into the Equation When Calculating Climate Change Risks
- Carbon Consequences of Tax System Reform
- Carbon Policy and Endogenous Technical Change
- Discounting in Intergenerational Decisionmaking
- Economic Analysis of Greenhouse Gas Emissions Trading
- Effective Environmental Policy in the Presence of a Distorted Tax System
- Electricity Restructuring and the Costs of Controlling CO₂
- Impacts of Climate Change Mitigation on Other Environmental Problems
- International Cooperation for Effective and Economic Greenhouse Gas Limitation
- Vulnerability of Low-Income Households to the Hydrologic Effects of Climate Change

To broaden understanding of climate change concerns, RFF is also organizing workshops and producing a series of Issue Briefs. The first of these, "Climate Change Risks and Policies: An Overview," is the source of Michael Toman's article.

For more information:

<http://www.rff.org/research/programs/climprog.htm>

and centuries, not just on the emissions of these gases over a relatively short period of time. We are dealing with the cumulative effect of many smaller influences on the biosphere—an effect with a great deal of natural inertia.

Having to confront the distant future greatly complicates risk assessment and the development of consensus for policy actions. To be effective, at least some actions must anticipate long-term impacts, before all of the scientific evidence is clear. Our political system

arguably is less effective at taking such actions than responding to a single large and immediate concern. On the other hand, the long-term nature of climate change risks means we can hone our scientific understanding and policy responses over time; we need not do everything right away.

Address adaptation. In areas such as agriculture, managed forestry, and human settlements, intuition and experience in other contexts suggest a medium-to-high degree of potential adaptability to natural changes, given enough lead time and investment. Adaptation possibilities include development of new plant varieties and crop patterns, changes in irrigation technology, relocation of coastal infrastructure, and expanded protection of wetlands to compensate for their potential future damage.

Adaptation may be difficult in some cases, for example, where damage occurs to natural ecosystems whose functions are not well understood. But even when adaptation capacity seems very limited, it should not automatically be treated as negligible. Improving the capacity to adapt where it is weak—as in many poor, developing countries—may be one of the most effective ways to respond to some climate change risks, at least until the cost of stabilizing atmospheric concentrations of greenhouse gases falls.

Think internationally. Rich and poor countries argue over how the burden of greenhouse gas emissions reductions should be allocated. The ongoing tension can only be resolved by negotiation among the parties themselves. However, long-term global climate change risks will not diminish to any significant degree until total global emissions are reduced, and this will require global cooperation, not just action by today's rich countries. This point deserves to be underscored in light of the likely future decline in the share of total emissions from advanced industrial countries (currently about 50 percent) as economic growth proceeds in other areas. The efficacy of any policies the United States pursues to reduce climate change risks thus will depend on the actions taken by others.

Keep distributional issues in mind. Climate change risks and response capacities vary with income level. There is also a fundamental asymmetry between the timing of response costs—which will largely be borne by the current generation—and the benefits of reduced climate change—which will largely accrue to future generations. This asymmetry means we cannot simply

compare the costs of reducing the risk with the value of enjoying the ultimate benefits. Instead, we must assess both the costs members of the current generation would bear and the strength of our concerns for those who would be vulnerable in the future. These are economically and ethically complex questions about which we know little, and they require mature political debate.

Estimate control costs realistically. Some people argue that market inefficiencies are so rife, and opportunities for innovation so plentiful, that emissions abatement is a low-cost proposition or one that might even benefit the economy. This point of view is in sharp contrast to the outputs of economic models indicating that stabilizing emissions may cost as much as several percent of a country's gross domestic product (implying that deeper cuts in emissions to reduce greenhouse gas concentrations in the atmosphere would be even more expensive).

Most people who have looked at the debate seem to agree that some low-cost improvements in energy efficiency exist, for example, by reducing subsidies and other market distortions. However, it is open to question whether these opportunities are substantial compared with, say, the amount of abatement needed to stabilize greenhouse gas emissions. Against the backdrop of future increases in global energy demand, the cost of longer-term reductions in greenhouse gas emissions cannot help but rise unless further progress occurs in the development of nonfossil energy alternatives. In assessing medium- to long-term costs, it is a mistake to assume technical progress as a panacea for reducing abatement costs, or no technical progress at all.

Another argument is that our tax system is so distorted that we can levy energy taxes to reduce greenhouse gas emissions and use the proceeds to lower other taxes that hamper economic growth. However, recent analysis calls into question this "double dividend." The basic conclusion of this analysis is that broader-based taxes like those on income generally create less overall economic distortion than narrower-based taxes like those on energy. Thus, adjusting other taxes might dull the economic pain of an added energy tax, but not to negligible levels. Moreover, any tinkering with the tax system is possible only if politicians take the difficult step of imposing higher energy taxes in the first place.

RFF Council Takes Up Climate Topic

The RFF Council took up the topic of "Climate Change: Policy Issues and Options" at its seventh annual meeting in April. Council members heard from scientists as well as experts in government, academia, and the business and environmental communities on this critical and controversial issue.

In a plenary session on how to think about climate change policy, RFF Senior Fellow Michael Toman was joined by American Petroleum Institute Executive Vice President William O'Keefe and Daniel Lashof, a senior scientist at the Natural Resources Defense Council. Toman and RFF Senior Fellow Raymond Kopp later led respective discussions on technical responses to climate change and implementation of policies.

Rafe Pomerance, the U.S. Department of State's deputy assistant secretary for environment and development, spoke of the challenges of negotiating international climate agreements. Everett Ehrlich, the U.S. Department of Commerce's under secretary of commerce for economic affairs, discussed the implications of climate change policies as they might affect the United States in particular.

Most studies of greenhouse gas abatement costs assume the application of idealized least-cost policy measures like a comprehensive "emissions trading" program or a comprehensive "carbon tax" based on the carbon content of different fossil fuels. Abatement costs will be higher (perhaps considerably so) if less than ideal policies are used in practice. The debate about which greenhouse gas reduction targets are appropriate cannot be conducted independent of discussions about what concrete measures can and should be used to actually restrict emissions.

Implications for Policymaking

The decision framework I have described has several implications for formulating policy.

Allow flexibility in the timing of cumulative emissions reductions to reduce overall costs. The potential cost savings from intertemporal flexibility in meeting a particular long-term emissions-reduction goal depend on the assumptions made, but it appears that savings of at least 20 percent or more are possible. Taking this approach

does not mean that all or even most policy actions are deferred to the future. It simply means that the emphasis is placed on sequential decisions—some of which are better taken sooner and others later. Unless we start with a longer-term perspective, it is impossible to consider such tradeoffs.

Incorporate economic incentives into emissions-reduction policy.

These incentives include carbon taxes on energy sources and various forms of tradable permit systems that would effectively establish quotas on emissions but allow their trade. Sources with higher control costs could (in effect) pay emitters with lower control costs to assume more of the reduction burden.

Provide opportunities for emissions reductions wherever possible.

One example of an abatement incentive program that takes place outside industrialized countries is the so-called "joint implementation" approach, whereby emitters in, say, the United States, can satisfy any emissions reductions requirements they face through actions that reduce emissions in other countries.

Formal emissions trading programs among sources in countries with quantified emissions reduction targets also are possible. Significant practical questions need to be answered to structure flexible yet verifiable programs for international (and intertemporal) emissions trading. However, the magnitude of the potential cost savings underscores the value of seeking to overcome these challenges. Depending on the assumptions made, savings of 50 percent or more seem possible.

Build knowledge and improve technology. Even if we do all the best things possible to reduce emissions, given the current state of knowledge, economic growth—especially in developing countries—will continue to push up greenhouse gas emissions and atmospheric concentrations. Unlike limiting pollutant gases such as sulfur dioxide, for which a variety of technical control options is available, limiting carbon-dioxide emissions requires reduced energy use, greater energy efficiency, or substitution of energy sources with lower carbon content.

To avoid unacceptable climate change risks ultimately will require a fundamental change in our energy systems toward much greater reliance on other energy sources—solar, biomass, and possibly nuclear. To make the transition economically manageable will require continued or enhanced investments in basic and applied knowledge.

The government has an inescapable role to play not just in creating the incentives for private parties to seek better technologies but also in funding the development of basic knowledge about technology as well as climate change impacts. At the same time, we must recognize that our understanding of what policy can actually do to induce climate-friendly innovation is weak at best. We must also recognize that diverting resources from other areas to research on low-carbon energy systems may well reduce innovation elsewhere in the economy—technical progress is not a free good.

Increase emphasis on adaptation. Adaptation is part of an optimal response strategy in any event. Indeed, it is the means of transcending the narrower concern about our vulnerability to climate change to a broader concern with global-scale changes that place stress on natural systems and pose threats to human well-being. Furthering human capacity to adapt to climate change entails investment in improved understanding of the options and their international application. It also entails adjusting economic and other distortions that limit adaptation potential (such as assistance programs that subsidize coastal development or water use). In many cases, the best climate policy may have little to do with greenhouse gases or climate per se, and much more to do with developing better basic social infrastructures for natural resource conservation and use and for public health protection.

Michael A. Toman directs RFF's Energy and Natural Resources Division and coordinates its Climate Economics and Policy Program.

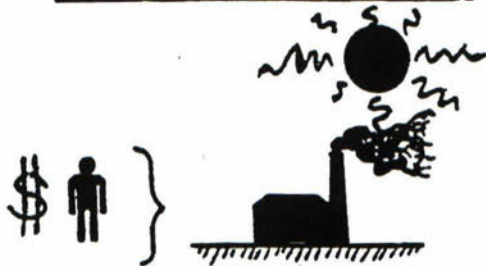
GLOBAL WARMING: WHAT WE KNOW & WHAT WE DON'T KNOW

DAN ALBRITTON - NAT'L OCEANIC & ATMOSPHERIC ADMINISTRATION (NOAA)

DEPUTIES COMMITTEE ON CLIMATE CHANGE
DOS, 19 NOVEMBER 1996

► CONTEXT: THE CLIMATE SYSTEM & HUMANKIND

• CLIMATE CHANGE FORCINGS



• PHYSICAL PROCESSES



• PHYSICAL RESPONSES



• BIOLOGICAL PROCESSES

- CROP YIELD
- COASTAL HABITATION
- FOREST MIGRATION
-

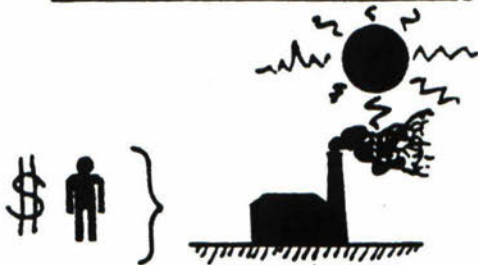
• IMPACTS



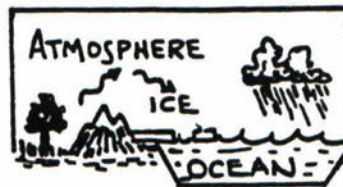
GLOBAL WARMING: WHAT WE KNOW & WHAT WE DON'T KNOW

► CONTEXT: THE CLIMATE SYSTEM & HUMANKIND

• CLIMATE CHANGE FORCINGS



• PHYSICAL PROCESSES



THREE MAJOR QUESTIONS:

★ • HOW WELL DO WE UNDERSTAND THE CLIMATE SYSTEM & OUR ROLE IN CHANGING IT?

• HOW WELL CAN WE CHARACTERIZE THE IMPACTS OF CLIMATE CHANGE?

• WHAT ARE OUR FUTURE OPTIONS?



• PHYSICAL RESPONSES



• BIOLOGICAL PROCESSES

- CROP YIELD
- COASTAL HABITATION
- FOREST MIGRATION
- ...

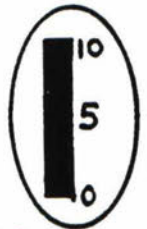


• IMPACTS

A SCIENTIFIC STATUS REPORT



THERE IS A NATURAL GREENHOUSE EFFECT.
IT KEEPS THE EARTH WARMER THAN
IT WOULD BE OTHERWISE.



"CONFIDENCE
INDEX"

POINTS...

● IN TERMS OF BASIC PHYSICS:

ⓑ IT WARMS UP AND...

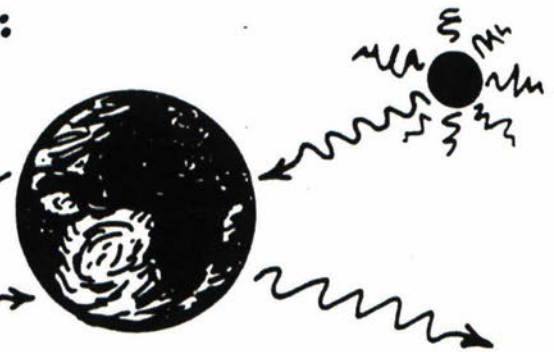
ⓒ IT EMITS INFRARED LIGHT.



Ⓐ IF AN
OBJECT IS
BATHED IN VISIBLE LIGHT...

● IN TERMS OF OUR PLANET EARTH:

<u>ATMOSPHERE</u>	<u>ABUNDANCE</u>
NITROGEN	78%
OXYGEN	20
⋮	
★ WATER VAPOR	2%
CARBON DIOXIDE	0.03
⋮	
↗ GREENHOUSE GASES	



● KEY ASPECTS

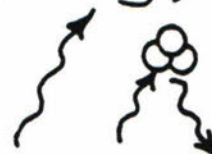
> WATER VAPOR & CARBON DIOXIDE HAVE BEEN PART OF OUR
ATMOSPHERE FOR MILLIONS OF YEARS.

> THEIR PRESENCE YIELDS AN AVERAGE SURFACE TEMPERATURE OF ~60° F.

> WITHOUT THEM, THE AVERAGE WOULD BE ~5° F.

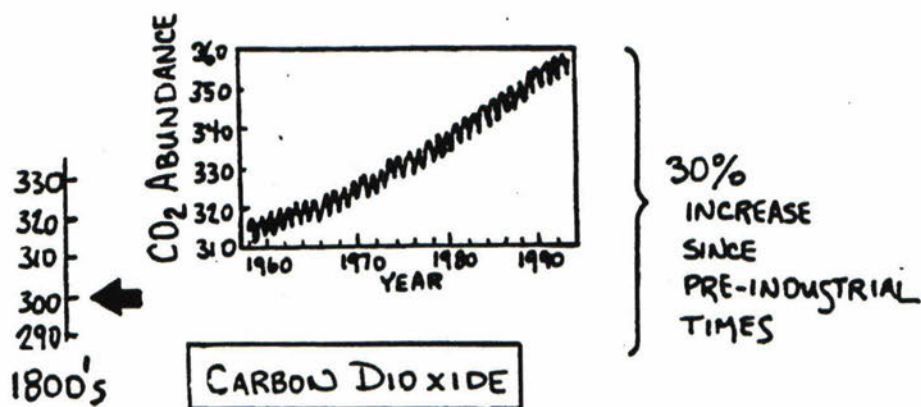
SO ... WHAT'S THE PROBLEM?

➡ GREENHOUSE GASES ARE INCREASING IN THE ATMOSPHERE BECAUSE OF HUMAN ACTIVITIES, AND THEY ARE INCREASINGLY TRAPPING MORE HEAT:



POINTS...

- IMPECCABLE SCIENTIFIC MEASUREMENTS



- OTHER GASES ARE INCREASING TOO

METHANE,
FOR EXAMPLE
 $\times 2+$

- THE SOURCES ARE HUMAN-CAUSED

$\text{CO}_2 \sim \text{ALL}$
METHANE $\sim \text{MOST}$

Q: BUT, WHAT ARE THE POTENTIAL CONSEQUENCES?

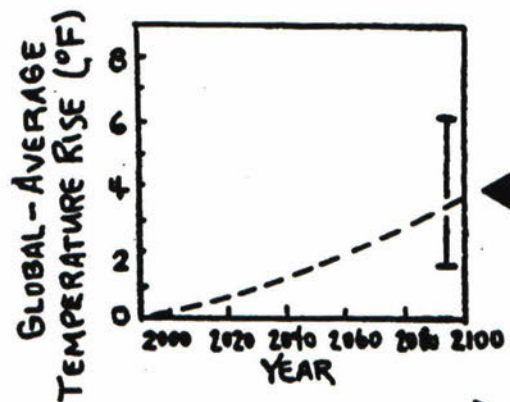
➡ A CONTINUED FUTURE GROWTH IN GREENHOUSE GASES IS PREDICTED TO LEAD TO VERY SIGNIFICANT CLIMATE CHANGES.

POINTS...

- CO₂ ABUNDANCE LIKELY COULD DOUBLE AROUND 2100

INDEED... TO STABILIZE AT DOUBLED → CUTS IN EMISSIONS
TO RETURN TO TODAY'S → DEEP CUTS

- PREDICTED CLIMATE RESPONSES.

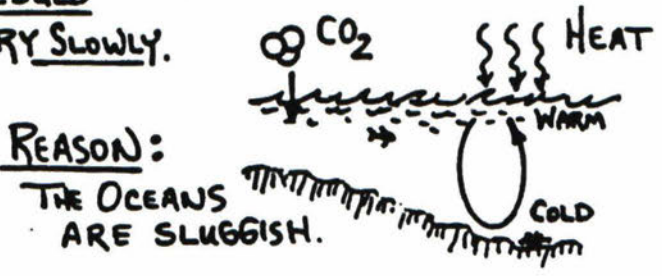


"BEST ESTIMATE": $3\frac{1}{2}$ °F INCREASE IN TEMPERATURES AVERAGED OVER THE GLOBE.

> IF SO, THIS WOULD EXCEED THE NATURAL CHANGES OVER THE PAST 10,000 YEARS.

> CORRESPONDING SEA LEVEL RISE: ~20 INCHES.

- A GREENHOUSE WARMING COULD ONLY BE REVERSED VERY SLOWLY.



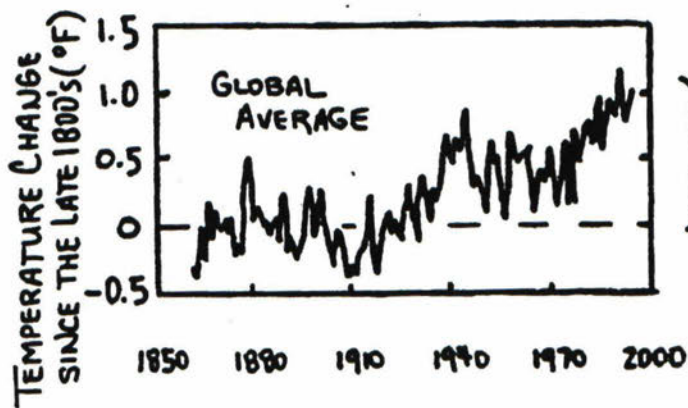
Q: HAVE WE SEEN ANY WARMING YET?



GLOBAL TEMPERATURES HAVE WARMED OVER THE PAST CENTURY & THE BALANCE OF EVIDENCE SUGGESTS A DISCERNABLE HUMAN INFLUENCE.

POINTS...

● GLOBAL TEMPERATURE MEASUREMENTS



THE EARTH (ON THE AVERAGE) HAS WARMED 0.5-1.0 °F OVER THE PAST 100+ YEARS.

> SLOW, NATURAL SWINGS IN TEMPERATURE SINCE THE LAST ICE AGE ARE NOT DISSIMILAR IN SIZE.

● THE OBSERVED WARMING IS UNLIKELY TO BE ENTIRELY NATURAL.

⇒ 1995 IPCC
"human activities likely influencing..."
only possible in 1995

REASONS:

COMPARISONS OF TEMPERATURE-CHANGE PATTERNS:

PREDICTIONS ↔ OBSERVATIONS

REGIONAL
SEASONAL
VERTICAL

PATTERN OF CHANGES
• PREDICTIONS
• OBSERVATIONS
TEND TO CORRESPOND

☑ CORRESPONDENCES INCREASE WITH TIME

☑ PROBABILITY IS LOW THAT A "NATURAL-ONLY" EARTH WOULD HAVE SUCH CORRESPONDENCES



Q: BEYOND "GLOBAL AVERAGES"?

➡ IT IS A COMPLEX PLANET & WE HAVE IMPERFECT KNOWLEDGE,
SO, PREDICTION OF FURTHER DETAILS SUFFERS.

POINTS...

● WHAT WILL HAPPEN IN PARTICULAR PLACES?



● REGIONAL CHANGES CANNOT YET BE PREDICTED RELIABLY.

- INDICATIONS ARE: • LAND WARMS MORE THAN OCEANS } WINTER.
- MAX N. HI-LATITUDE WARMING
- TEMPERATURES BETTER PREDICTED THAN RAINFALL.

● HOW ABOUT "EXTREME EVENTS"?

more exup, cawlection, etc.

> A WARMER WORLD → A MORE-VIGOROUS HYDROLOGICAL CYCLE

PERHAPS
MORE
VARIATION

FLOODS/DROUGHTS:
MORE OR LESS SEVERE,
FROM REGION-TO-REGION.

> HURRICANES: MORE/LESS FREQUENT? INSUFFICIENT KNOWLEDGE

● SURPRISES?

> ABRUPT CLIMATE SHIFTS?

> CURRENTLY UNKNOWN GEOPHYSICAL
PROCESSES ACTIVATED?

POSSIBLE. HERE'S WHY:

• ENTERING A NEW
REGIME OF CLIMATE
PERBATION.

• CLIMATE IS A NONLINEAR
SYSTEM:

CONCLUDING COMMENTS

● BOTTOM LINES THE VAST-MAJORITY SCIENTIFIC VIEWPOINT:

- THE ISSUE IS A REAL ONE.
- SOME HUMAN-INDUCED CLIMATE CHANGE APPEARS INEVITABLE.
- DISCERNABLE "FIRST SIGNS" ARE SUGGESTED NOW.
- EXACTLY WHERE (REGIONS)
WHEN (RATE OF CHANGE) IS HARD TO PREDICT.
HOW MUCH (MAGNITUDE)
- HUMAN-INDUCED CLIMATE CHANGE WOULD BE SLOW TO REVERSE.

● BASIS OF THIS INFORMATION

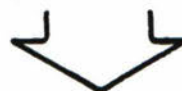
INTERGOVERNMENT PANEL ON CLIMATE CHANGE



OFF THE PRESS: APR/MAY '96

ASSESSMENTS:

- PREPARED BY EXPERT COMMUNITIES.
- INTERNATIONALLY BASED.
- "ONE-STOP SHOPPING" FOR THE ISSUE.



THE LAST BOTTOM LINE:

KEY INPUT
TO POLICY
DECISIONS



Energy: Production, Consumption,
and Consequences. 1990.
Pp. 75-84. Washington, D.C.:
National Academy Press.

Global Environmental Forces

THOMAS C. SCHELLING

Greenhouse warming is global in at least two respects. First, carbon dioxide (CO_2) and the other gases released or withheld anywhere on earth disperse rapidly into the global inventory. The location of origin makes no difference. Second, the effect will be a change in global circulation of air and water. Although the mean rise in atmospheric temperature is commonly used as an index of climate change, the change in temperature differential between equatorial and polar regions may be a better measure of global environmental forces.

The standard point estimate of global warming for a doubling of the concentration of CO_2 in the atmosphere is 3°C (National Research Council, 1982). But it is usually estimated that the warming in the polar regions associated with this 3-degree average change might be 8 or 10 degrees, whereas the change in atmospheric temperature near the equator might be closer to 1 degree (National Research Council, 1982). Offhand this sounds like a welcome dispersion of temperature change: it will mainly get warmer where it is already very cold and warm up the least where it is already hot. But more significant is that it is the temperature gradients between equatorial and polar regions that drive the winds, which in turn drive the oceans, and a change of 7 or 8 degrees in the mean temperature *difference* will change the atmospheric and oceanic circulation much more than would a uniform global rise in atmospheric temperature. Most climates may get warmer, some will undoubtedly become cooler. But the observed changes will include not only temperature and temperature variation from season to season and year to year but also, probably more importantly, the amounts,

the seasonal distribution, and the year-to-year variation in rainfall, snow, wind, fog, sunlight, humidity, and storms.

For the purpose of comparing forthcoming changes in climate with changes experienced in the past, the mean global atmospheric temperature is probably not only a reliable index but something of a measure of magnitude. Using the commonly accepted 3-degree rise from a doubling of the atmospheric concentration as an approximation to what may be forthcoming, the ensuing temperature will not only be well outside the range of atmospheric temperatures experienced in the past 10,000 years but may be several times the range of temperature variation experienced in that time. This observation is frequently expressed, and correctly, as a change in climate greater than any that mankind has experienced since the dawn of history. It is expressed more accurately as changes in *climates*—plural not singular—because different climates around the globe will change differently.

Without belittling the unprecedented nature of such climate changes or the prospect of some change that is not gradual but catastrophic, it is fair to point out that most people will not undergo in the next 100 years changes in their local climates more drastic than the changes in climate that people have undergone during the past 100 years. No climate changes are forecast that compare with moving from Boston to Irvine, California, or even perhaps from Irvine to Los Angeles. The Goths and the Vandals, the Romans and the Vikings, the Tartars and the Huns migrated through more drastic changes than any currently anticipated; Europeans who migrated to North and South America similarly underwent drastic climate changes. In this country in 1860 barely 2 percent of the population lived outside the humid continental or subtropical climates; in 1980 the percentages outside these zones had increased from 2 percent to 22 percent.

Furthermore the microclimates of urbanized Tokyo, Mexico City, and Los Angeles have not deterred their population growth; the microclimates of London and Pittsburgh changed dramatically during the century before 1950 and have changed again almost as dramatically since then. Even urbanization itself, without the associated air pollution, changes the conditions created by climate. Most Americans, Europeans, and Japanese never experience muddy roads anymore.

The expectation is that climates will change gradually, both over time and over space (National Research Council, 1983:Ch. 1-3). The climate of Nebraska may gradually change into the current climate of Kansas, not into the climate of Massachusetts or Oregon. Climates will "migrate." This expectation is on the whole reassuring, but it could be mistaken. The models used in the computer simulation of climate may be incapable of producing discontinuities because the current state of meteorological knowledge is confined to continuous processes. There may be no reason to expect

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discontinuities, but the fact that the models produce no discontinuities may reflect an inability to design models based on the state of the art that can discover such phenomena.

Aside from a possible rise in ocean level, which I shall discuss presently, the most predictable physical and economic consequences of climate change will be in agriculture. By "predictable" I mean not that the actual changes can be predicted but that it can be reliably predicted that there will be changes. These will be changes in rainfall, winter snow for summer irrigation, humidity, daylight and cloud cover, and perhaps the health and comfort of livestock.

There is no reason to believe that the revolutionary improvements in agricultural productivity that have developed over the past 75 years and that in many cases have spread worldwide will not continue. Depletion of soils may continue, but control over plant and animal genetics and the possible production of new proteins may drastically change for the better what crops people will grow and what foods they will eat 50 or 100 years from now. An increase in the cost of food production by 5 or 10 percent, even 20 percent, which would be a somewhat extravagant estimate, may easily be offset many times over by another century's improvements in agricultural productivity.

There will undoubtedly continue to be parts of the world that are intractably poor and dependent for a livelihood largely on local production of food or other climatically dependent crops. These countries may have little of the capacity to adapt that the more advanced countries can afford. So even if the damage to food production may not average enough on a global scale to be cause for alarm—may not even be noticeable—there may be particular areas in which the damage to agriculture coupled with population growth could severely retard progress. (Population growth may be the more serious.) This situation may demand foreign aid to the poorest countries. I would neither expect nor recommend foreign aid directly related to hardships induced by climate change, but rather aid to the poorest.

What I have said so far will sound to many readers as insufficiently alarmist. "Optimistic" it may appear. One reason for the unexcited tone, which I shall elaborate shortly, is pessimism, not optimism. I do not believe that serious measures will be taken over the next quarter century to curtail the emissions of carbon into the atmosphere. I do not believe that even an alarmist appraisal will lead to a substantial policy response. I therefore do not believe that exaggerating the dangers will serve a useful purpose.

But there is, I acknowledge, another reason why my assessment is so mild. As I mentioned earlier, I am attempting to assess predicted changes, and it may be that our climate models predict only what we understand well enough to include in the models. Maybe we are also good at adapting to

phenomena we understand, as well as good at predicting them; and the ones we do not understand well enough to predict will cause difficulty because we do not understand them well enough to adapt. In other words, there is bias in our assessment of dangers: those we understand well enough to perceive we understand well enough to overcome, those that we have no hints of may be the dangers we would least know how to meet and overcome. Reduced rainfall in Kansas 25 or 50 years from now we may adapt to with moisture-conserving agricultural techniques, genetically altered crops that require less moisture, or the acquisition and transport of water. The phenomenon is familiar, the adaptations are familiar, and the predictions are based on familiar principles of meteorology. The "collapse" of the West Antarctic Ice Sheet would be an altogether different phenomenon.

As recently as 15 or 20 years ago, the accepted estimates were that the grounded ice—ice resting on the sea bottom and rising a kilometer or more above sea level—might, with a warming of the oceans attendant upon a warming of the atmosphere, slide or glaciote into the ocean within 75 years, causing a 20-foot rise in sea level. Like seismology in response to the test-ban controversy of the 1950s, glaciology has advanced in the past decade or two, assisted by satellite sensing, and the currently accepted estimates are that if that grounded ice should be added to the ocean level it is likely to be gradual and to take several hundred years. The urgency of that particular danger is thus reduced by an order of magnitude (unless further rapid advances in the relevant glaciology bring comparable changes in estimates back in the opposite direction). What is worrisome is that there may be other phenomena, perhaps, like the ocean level, not being perceived as "climatic," that could be as devastating as a 20-foot rise in sea level and that will not, upon further inspection, yield to more benign estimates.

When asked for an example, I can of course protect myself by pointing out that predicting the unpredictable, foreseeing the unforeseen, especially as an amateur, cannot be demanded of me. But when I am in a mood to worry I think about possible changes in the Gulf Stream and the Japanese current. The current global circulation models, as I understand it, do not include changes in the direction and velocity of ocean currents, and I am not sure that enough is known about the response of ocean currents to changes in wind patterns to predict whether there may be *catastrophes*, that is, flipflops from one equilibrium to another, rather than gradual change. Thus, there may be a missing feedback loop from warming to winds to currents to climate that, when added to the current models, will produce something more worrisome than the migration of the climate of Kansas to South Dakota.

As I said at the outset, the problem is global; and that is why it is exceedingly unlikely that anything substantial will be done to curtail fossil

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fuel emissions. Any nation that attempts to mitigate changes in climate through a unilateral program of energy conservation or fuel switching (or expensively scrubbing CO₂ from smokestacks) in the absence of some international rationing or compensation arrangement, pays alone the cost of its program while sharing the benefits with the rest of the world. Consider the Federal Republic of Germany, which accounts for about 4 percent of world's energy consumption and just about 4 percent of each of the three fossil fuels, coal, oil, and natural gas. If that country took the drastic step of reducing by one-third its consumption of fossil fuels, the cost in lost productivity and consumer welfare, even if it were done gradually over a period of two decades, could be equivalent to 3-4 percent of its gross national product while the concentration of CO₂ in the atmosphere would be reduced by barely 1 percent. Even for the United States, the largest energy consumer of all, phasing in a one-third cutback in fossil fuel consumption over the next 20 years at a cost perhaps equivalent to \$150 billion or \$200 billion per year at today's prices and income levels, would reduce emissions worldwide by less than 10 percent. The time to a doubling of CO₂ in the atmosphere might be reduced from something like 85 years to 80 years. I think it is a fair estimate that for no individual country, with the arguable exception of the United States, is it economical to curtail CO₂ emissions unilaterally in the interest of retarding climate change.

Any significant effort to curtail emissions would require an international rationing regime, covering the larger fraction of world energy consumption, to ration the consumption of energy, or the consumption of fossil fuels, or the consumption of carbon, in some manner that could confidently be expected to remain in force long enough to be effective, say 50 years or more. It would have to include the Soviet Union, it would have to include the People's Republic of China, and it may well have to include the Organization of Petroleum Exporting Countries (OPEC). It would require mandating compliance on the part of scores of nations that would greatly prefer to be outside the regime. And it would require for many nations trading urgently needed economic growth now for the dubious future benefits of a rationing scheme that depended on a more disparate membership than even that of OPEC. Eventually, because most of the world's known coal resources are in the Soviet Union, China, and the United States, the scheme would require those three nations to collaborate effectively and indefinitely as a cartel.

The political likelihood of solid and confidently expected collaboration of that kind would be approximately zero if energy were a homogeneous commodity consumed uniformly worldwide. But to put in effect a rationing scheme the impact of which will begin to hurt and be effective only after several decades of energy growth would require dealing with economic growth itself, and that in turn requires attention to things like population

growth (Ausubel and Nordhaus, 1983; Nordhaus and Yohe, 1983). Do the Chinese claim that a policy of zero population growth is more than sufficient as a curtailment of energy use and that their country should therefore be exempt? Do the countries in the Organization for Economic Cooperation and Development participate as a unit, negotiating long-term shares in energy growth? Is there any chance they could be more successful than they have been with defense budgets, oil imports, or agricultural trade?

My pessimistic conclusion is that nothing of the sort is going to happen. I do not believe the Montreal Protocol on Substances that Deplete the Ozone Layer, signed in September 1987, is any harbinger for suppression of CO₂. Economically what is at stake is two or three orders of magnitude greater for fossil fuels than for chlorofluorocarbons (CFCs) and the prospects for technological replacement of CFCs are much brighter. (The Ozone Protocol does illustrate the need for worldwide collaboration to make restrictions worthwhile: the treaty takes effect only when ratified by nations representing two-thirds of world consumption.)

If world politics change as much in the next 75 years as in the past 75, a global fuel regime of some kind may become possible, but none is now foreseeable. If I am wrong, and world rationing of fossil fuels becomes economically and politically feasible, we shall still face the prospects for climate change. There is absolutely no possibility that fossil fuel emissions can cease altogether in the foreseeable future, and even the most optimistic could hardly hope that fuel emissions would stop growing within the foreseeable future. A most ambitious goal might be to reduce by half the growth rate in fossil fuel emissions. (As the fraction of fossil fuels represented by petroleum and natural gas declines over the coming century, fossil fuel consumption will have to increase at less than half the unrestricted growth rate in order that carbon emissions be only half what they might otherwise be.) A not unreasonable estimate, for purposes of illustration only, of growth in fossil fuel consumption over the next half century might be 2 percent per year, a rate at which the atmospheric concentration of CO₂ might double in about 85 years, reaching 50 percent elevation in about 50 years. Holding emissions to 1 percent growth would carry us beyond the middle of the next century before we reached concentrations half again as great as today's. The implied curtailment in emissions, at 1 percent compared with 2 percent, would be 10 percent at the end of the first decade, 25 percent at the end of three decades, and 40 percent by the end of five decades. That seems to me to be the outside limit to what might be economically acceptable worldwide. (How that 40 percent aggregate curtailment would be shared among consuming nations I hesitate even to conjecture.)

National programs to phase in nuclear power to replace fossil fuels for electricity, even for the production of hydrogen fuels, may again become popular. But it is still hard to measure the half-life of anxiety resulting from

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the accidents at Three Mile Island and Chernobyl. Any new reactors will have to be economical as well as clean. Cutting the growth of emissions from 2 percent to 1 percent may well require all electric power capacity in the future to be nuclear.

Energy conservation measures deserve emphatic attention, but investments in conservation will mainly be limited to what the private economy finds economical. National or international policy will probably be limited to research, development, demonstration, and technology transmission. Energy-efficient investments may yet get a boost from another doubling or more of the price of crude oil, but that is probably not a boost to be hoped for.

What else may be done to cope with the greenhouse problem? CO₂ can be removed from the atmosphere by increasing the mass of living vegetation or by "refossilizing" timber, burying it underground or in the ocean or coating it so that it cannot oxidize. And CO₂ can be scrubbed from smokestacks at very substantial expense. Probably at enormous expense, some attenuation could be achieved in this fashion. (Some small increase in the carbon density of forests may result naturally from the enhancement of CO₂ in the atmosphere.) The concentration of CO₂ will therefore certainly increase, and at an increasing rate, and I consider it unlikely that we shall be rescued much before the concentration has nearly doubled.

The main response will be adaptation, and most of that by ordinary people and businesses. Some of the adaptation will be by governments, but local and regional governments as much as national governments. There will be changing climates to cope with, changing urbanization, changing population densities, and in most countries probably drastic changes in the ways that people live and work and transport themselves, perhaps significant changes in what they eat. Much of the adaptation will seem generally "environmental" rather than specifically climate oriented. And, of course, there is continuous adaptation to climate even when it is not changing: we change the technology and the efficacy with which we heat ourselves and cool ourselves and clean our air and protect ourselves from storms and cope with droughts and floods and dispose of snow. The pace of change may be such that people will find themselves adapting to *climate* rather than to *changing climate*. Just as businesses shift to take advantage of better productive climates, they will keep shifting to better climates with perhaps small regard for the prospects of changing climates in given locations.

There remains to be discussed a response to climate change that receives so little attention that it deserves emphasis here—direct intervention in weather and climate. When Thomas F. Malone was chairman of the Committee on Atmospheric Sciences of the National Research Council, he wrote, 20 years ago, "The possibility that large effects may be produced

from relatively modest but highly selective human interventions opens up the possibility that weather and climate modification may some day be operationally feasible" (Malone, 1968:1136). And of the modification of hurricanes he said, "If five years are allowed for the development of an adequate mathematical model, five more years for assessing the consequences of interventions of various kinds, and then ten years of field experimentation for validation, it seems unreasonable to expect much before 1990, with the probabilities fair to good that a proven technology will exist by the year 2000." He added, "The probability of success in broad climate modification is likely to exceed 50 percent by the year 2018" (1968:1138), that being the 50-year mark from the time he wrote.

Most experiments with weather modification or with changing geographical features that may lead to climate change have been local and regional. That has been true of cloud seeding and would be true of the manipulation of hurricanes. In a discussion of greenhouse warming, the possibility of global intervention has to be considered. An important kind of human intervention in global climate may be efforts to change the radiation balance itself. We know it can be done: we are doing it. That is what the greenhouse discussion is all about. The fact that we are doing it unintentionally, and the fact that the consequences may not be welcome, do not contradict that we know how, at some expense if necessary, to change the world's climate more than it has changed in the last 10,000 years.

Warming the atmosphere currently is more economical than cooling it because it happens as a by-product of energy consumption that would be costly to reduce or terminate. If we were faced with a "little Ice Age" over the next century, we might be glad to get some of that CO₂ in the atmosphere at no cost and without having to negotiate climate change diplomatically.

But we know that, in principle, cooling could be arranged. Volcanic eruptions have done it. Discussions of "nuclear winter" took seriously the possibility that human activity might lower global temperatures cataclysmically. Considering the development of nuclear energy in both its explosive and its controlled uses and the feat of landing a team on the moon and returning it safely, and that we now know how to warm the earth's atmosphere and possibly to cool it (though through unacceptable means), we should not rule out that technologies for global cooling, perhaps by injecting the right particulates into the stratosphere, perhaps by subtler means, will become economical during coming decades.

A more benign example, compared with nuclear winter or induced volcanic eruptions, may be the manipulation of cloud cover. Let me again quote Thomas Malone (1968:1135).

A characteristic of the atmosphere that frustrates the weather forecaster while providing a basis for optimism on the part of the weather modifier is a tendency

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for the processes in the atmosphere to demonstrate certain traits of instability. . . . For example, a small puffy-type cloud may grow to a towering thunderstorm in a matter of hours; a gentle zephyr in tropical latitudes may develop into a "killer" hurricane in a matter of days; and a small low-pressure center may grow to a vigorous extratropical cyclone within a single day. . . . An avenue may be opened up by which great effects may be produced from relatively modest but highly selective human interventions.

If somebody learned in the next 50 years how to affect the extent and global distribution of certain kinds of cloud cover, incoming radiation may become manipulable by nations, international agencies, or even interested private organizations, depending on the nature of the technology, its expense, and perhaps geographical considerations.

It is difficult to mention such a possibility without appearing to recommend it, or to use it as a "technological fix" in the future to divert attention from some need for immediate policy intervention. I am not recommending, I am predicting. Independently of CO_2 , we have to consider that weather and climate modification may become feasible in a period of time no longer than the elapsed time since electronics, genetics, antibiotics, and nuclear fission were unimagined. The greenhouse warming may generate an interest among most nations in moderating the changed radiation balance, and if it proves more expensive to facilitate outgoing radiation than to obstruct incoming, there may be powerful motives for considering it. And if the technique for moderating incoming radiation were globally uniform or nearly so, an international agreement would have only to decide how to share the costs, a unidimensional problem compared with sharing the reduction of emissions.

If intervention is more regional than global, or global but not uniform in its distribution, intervention could become exceedingly controversial. Mexico and China are counting on those hurricanes—they are an essential source of rainfall for crops—whereas the Cubans, Filipinos, Japanese, and residents of the Texas coast would suppress them if they knew how.

In closing I must say a word about sea level. I believe the current wisdom is that we may be in for rising sea level that could be on the order of a meter per century for several centuries (Robin, 1986). Anything upwards of a meter, perhaps even half a meter, would primarily be due to the collapse of the West Antarctic Ice Sheet. The full 20-foot rise corresponding to the complete disappearance of that body of ice would put the White House rose garden under water, make Beacon Hill in Boston an island, and isolate the southern third of Florida by making the middle third disappear under water.

A country like the United States should be able to adapt (eventually by doing, perhaps, what the Dutch have been doing for centuries—constructing dikes). No such "easy" solution is available to a country like Bangladesh, which is densely populated in large areas that would be inundated by the

full sea level rise, and which could not be protected with dikes. (If dikes were erected along the coastline to protect against seawater flooding, the area would simply be flooded with fresh water that could not flow out to sea.)

If current estimates hold up, the potential devastation of rising sea level will mainly be 100 years away, and the government of Bangladesh should worry much more about population and productivity than climate change. If the more prosperous nations were prepared to help Bangladesh at great expense to themselves, aid now would probably appeal more to Bangladesh than heroic efforts to forestall floods a century hence. (That country already has floods to cope with in this century!)

Estimates of rising sea levels depend not only on thermal warming of the oceans, melting of glaciers, and what happens to the West Antarctic Ice Sheet; they can also depend on what happens to the Antarctic climate. There has been some conjecture that a warming of the South Polar air may lead to greater snowfall on Antarctica. The area of Antarctica is about one-fortieth the area of the oceans; a 1-centimeter rise in ocean level would be offset by a 40-centimeter rise in the water content of the snowfall on Antarctica, or an average snowfall of 4 meters per year. Storing water as ice on Antarctica might be the ideal solution to the water-level problem. Even the people most offended at the thought of deliberately tampering with our climate to offset the greenhouse gases may agree that learning to make it snow on Antarctica is a worthwhile project for the next century.

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Reflections on the Economics of Climate Change

William D. Nordhaus

Albert Einstein's reaction to quantum mechanics was "God does not play dice with the universe." Yet mankind is playing dice with the natural environment through a multitude of interventions—injecting into the atmosphere trace gases like the greenhouse gases or ozone-depleting chemicals, engineering massive land-use changes such as deforestation, depleting multitudes of species in their natural habitats even while creating transgenic ones in the laboratory, and accumulating sufficient nuclear weapons to destroy human civilizations. As natural or social scientists, we need to understand the human sources of these global changes, the potential damage they cause to natural and economic systems, and the most efficient ways of alleviating or removing the dangers. Just as towns in times past decided on the management of their grazing or water resources, so must we today and in the future learn to use wisely and to protect economically our common geophysical and biological resources. This task of understanding and controlling interventions on a global scale can be called managing the global commons.

The issue analyzed in this symposium is the threat of greenhouse warming. Climatologists and other scientists warn that the accumulation of carbon dioxide (CO₂) and other greenhouse gases is likely to lead to global warming and other significant climatic changes over the next century. Many scientific bodies, along with a growing chorus of environmental groups and governments, are calling for severe curbs on the emissions of greenhouse gases. In response, governments have recently approved a framework treaty on climate change to

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monitor trends and natural efforts, and this treaty formed the centerpiece of the Earth Summit held in Rio in June 1992.¹

Natural scientists have pondered the question of greenhouse warming for a century. Only recently have economists begun to tackle the issue, studying the impacts of climate change, the costs of slowing climate change, and alternative approaches for implementing policies. The intellectual challenge here is daunting for those who take policy analysis seriously, raising formidable issues of data, modeling, uncertainty, international coordination, and institutional design. In addition, the economic stakes are enormous, involving investments on the order of hundreds of billions of dollars a year to slow or prevent climate change.

My purpose here is to provide a non-technical introduction to the economics of climate change. I will sketch the scientific background and uncertainties, survey the results of existing studies of the impacts of climate change, present a summary of a study of efficient policies to slow global warming, and end with the uncertainties that haunt the entire field.

The Scientific Background

What is the greenhouse effect? It is the process by which radiatively active gases like CO_2 selectively absorb radiation at different points of the spectrum and thereby warm the surface of the earth. The greenhouse gases are transparent to incoming solar radiation but absorb significant amounts of outgoing radiation. There is no debate about the importance of the greenhouse effect, without which the Earth's climate would resemble the moon's.²

Concern about the greenhouse effect arises because human activities are currently raising atmospheric concentrations of greenhouse gases. The major anthropogenic greenhouse gases are carbon dioxide (emitted primarily from the combustion of fossil fuels), methane, and chlorofluorocarbons (CFCs)—but of these CO_2 is likely to be the most significant over the coming decades. Scientific monitoring has firmly established the buildup of the major greenhouse gases over the last century. Using the standard but problematical metric of the " CO_2 equivalent" of greenhouse gases,³ atmospheric concentrations of greenhouse gases have risen by over half of the preindustrial level of CO_2 .

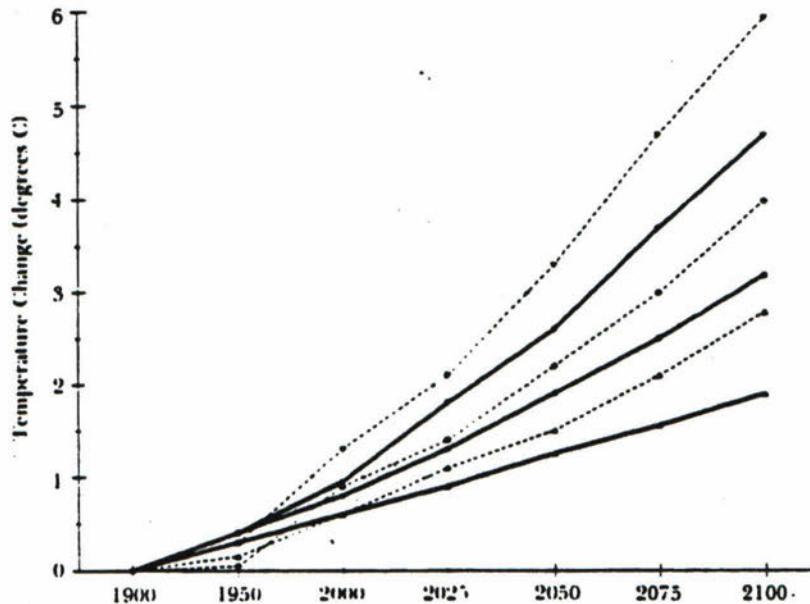
While the historical record is well established, there is great uncertainty about the potential for future climate change. On the basis of climate models,

¹Formally known as the United Nations Conference on Environment and Development (UNCED), the Earth Summit was the culmination of an effort to reach international agreements on climate, forest, biodiversity and biotechnology, as well as to develop principles for environmentally sound economic development.

²A non-technical description of the science underlying the greenhouse effect is contained in National Academy of Sciences (1992). A thorough survey, full of interesting figures and background, is contained in IPCC (1990).

³Because greenhouse gases have differing lifetimes, combining them into a single index of their " CO_2 equivalent" poses complex scientific and economic questions, as Schmalensee (1993) shows.

Figure 1
Projections of Global Temperature Increase:
IPCC Report and DICE Model



Note: IPCC Report is from Intergovernmental Panel on Climate Change (1990), while DICE model is from Nordhaus (1993). The dashed lines are from IPCC Report and represent, from top to bottom, high estimate, best estimate, and low estimate. The solid lines are from the DICE model and represent, from top to bottom, the 90th, 50th, and 10th percentiles of calculated temperature increases from 500 Monte Carlo runs. In both cases, the changes represent temperature increases from 1900.

scientists project that a doubling of the atmospheric concentrations of CO_2 will in equilibrium lead to a warming of the earth's surface of 1 to 5 degree Celsius; other projected and equally uncertain effects include an increase in precipitation and evaporation, a small rise in sea level over the next century, and the potential for hotter and drier weather in mid-continental regions such as the U.S. midwest. Atmospheric scientists have engaged in a spirited debate about the climatic impact of increasing greenhouse-gas concentrations, but it is unlikely that the uncertainties will be resolved until this vast geophysical experiment has run its course.

To translate these equilibrium results into a projection of future climate change requires a scenario for emissions and concentrations. Using rudimentary economic modeling, the Intergovernmental Panel on Climate Change (or IPCC), an international panel of distinguished scientists, projected that "business as usual" would produce a 3 to 6 degree C warming in 2100 (relative to 1900) with the best guess being 4 degrees C. The dashed lines in Figure 1 show the high, best, and low estimates from the IPCC.

I have recently used a dynamic optimization model (the DICE model, described more fully later in this paper) to develop a distribution of future

temperature increases. Figure 1 shows as solid lines the 10th, 50th, and 90th percentiles of the temperature-increase distribution from the DICE model. In general, economic models project rising relative energy prices and slowing economic growth in the coming decades; as a result, they tend to show lower emissions and temperature trends than the extrapolative approaches often used in the scientific community and exemplified by the IPCC projections. However, virtually all projections are worrisome because climate appears to be heading out of the historical range of temperatures witnessed during the span of human civilizations.

Climate models resemble large macroeconomic models in their ability to answer virtually any question that modelers care to ask. However, the reliability of climate models for global climate changes is unproven, and climate modelers do not expect to be able to forecast regional climates accurately in the foreseeable future. Some believe that there may be "regime changes" in which the climate flips from one locally stable equilibrium to another, say because of changes in ocean circulation. Elaborating bigger and better models will provide fruitful full employment for climatologists well into the next century.

Impacts of Climate Change

What are the likely impacts of projected climate changes over the next century? To begin, we should recognize that in the long march of economic development, technology has increasingly insulated humans and economic activity from the vagaries of climate. Two centuries ago, work and recreation were dictated by the cycles of daylight, the seasons, and the agricultural growing season.

Today, thanks to modern technology, humans live and thrive in virtually every climate on earth. For the bulk of economic activity, variables like wages, unionization, labor-force skills, and political factors swamp climatic considerations. When a manufacturing firm decides between investing in Hong Kong and Moscow, climate will probably not even be on the list of factors considered. Moreover, the process of economic development and technological change tend progressively to reduce climate sensitivity as the share of agriculture in output and employment declines and as capital-intensive space heating and cooling, enclosed shopping malls, artificial snow, and accurate weather or hurricane forecasting reduces the vulnerability of economic activity to weather.

In thinking about the impact of climate change, one must recognize that the variable focussed on in most analyses—globally averaged surface temperature—has little salience for impacts. Rather, variables that accompany or are the result of temperature changes—precipitation, water levels, extremes of droughts or freezes, and thresholds like the freezing point or the level of dikes and levees—will drive the socioeconomic impacts. Mean temperature is chosen because it is a useful *index* of climate change that is highly correlated with or

determines the more important variables. Moreover, it must be emphasized that impact studies are in their infancy and that studies of low-income regions are virtually non-existent.

Existing research uses a wide variety of approaches including time-series analysis, engineering studies, and historical analogs. Climate change is likely to have different effects on different sectors and in different countries.⁴ In general, those sectors of the economy that depend heavily on unmanaged ecosystems—that is, are heavily dependent upon naturally occurring rainfall, runoff, or temperatures—will be most sensitive to climate change. Agriculture, forestry, outdoor recreation, and coastal activities fall in this category. Countries like Japan or the United States are relatively insulated from climate change while developing countries like India are more vulnerable.

This survey of impacts will concentrate primarily upon the United States, because that is where the evidence is most abundant. In reality, most of the U.S. economy has little direct interaction with climate. For example, cardiovascular surgery and parallel supercomputing are undertaken in carefully controlled environments and are unlikely to be directly affected by climate change. More generally, underground mining, most services, communications, and manufacturing are sectors likely to be largely unaffected by climate change—sectors that comprise around 85 percent of GDP.

A few studies have estimated the impact of an equilibrium CO₂ doubling (2.5 to 3 degrees C) on the United States, and the results of three such surveys are shown in Table 1. The first column of Table 1 shows the results of Nordhaus (1991) updated to 1988 prices. The other two comprehensive studies by Cline (1992) and Fankhauser (1993) use largely the same data base but extend the Nordhaus analysis to other sectors. The convention used in most damage studies is to calculate impacts in terms of today's level and composition of output. Hence, the \$53 billion estimate of damage from CO₂ doubling estimated by Cline and shown in Table 1 superimposes the estimated impacts that would occur roughly a century from now upon today's economy.

Cline has performed the most detailed economic analysis of the potential impact of climate change on a number of market and non-market sectors, and the overall results are shown in the second column of Table 1. While Cline examined a wide variety of possible impacts, many of the estimates are extremely tenuous and may lean toward overestimating the impacts. For example, Cline's estimates of the impact of losses from storms assume that storms become more severe, whereas both the IPCC and the National Academy studies concluded that the effect of warming on storm intensity is ambiguous. Another example is leisure activities, where he includes only losses to skiing but excludes any gains from the much larger warm-weather industries such as camping.

⁴An early review, emphasizing the potential costs of climate change, is contained in EPA (1989). A more balanced approach, emphasizing the potential for adaptation, is contained in National Academy of Sciences (1992).

Table 1

**Comparison of Estimates of Impact of Global Warming on the United States:
Impact on Incomes of CO₂ Doubling**
(in billions of 1988 U.S. dollars per year)

	<i>Nordhaus</i>	<i>Cline</i>	<i>Fankhauser</i>
Heavily affected sectors			
Agriculture	1	15.2	7.4
Coastal areas	10.7	2.5	2.3
Energy	0.5	9	0
Other sectors	38.1		
Wetland and species loss	^b	7.1	14.8
Health and amenity	^b	8.4	30.3
Other	^b	11.2	12.1
Total: billions of \$	50.3	53.4	66.9
(Percent of output)	1.0	1.1	1.3

^aReferences are Nordhaus (1991), Cline (1992), Fankhauser (1993).

^bThese are included in the total for "other sectors."

boating, and swimming. In agriculture, Cline relies on estimates that involve little or no adaptation. For health effects, Cline bases his estimates on a study that virtually ignores adaptation. For species loss, Cline takes a very costly decision (that of the Northern spotted owl) and uses that as the basis for valuation. Even with this tendency to see the pessimistic side of global warming, Cline's estimates of impacts are only marginally above those found in other studies (1.1 percent of GNP for a 2.5 degree C warming in Cline, as opposed to 1 percent of GNP for a 3 degree warming in Nordhaus).

A third approach is a compilation by Fankhauser (1993). This study employs much the same methodology as Nordhaus and Cline but uses additional studies and extends the analysis to the OECD countries and to the world. Fankhauser's results are very close to those in earlier studies, finding a 1.3 percent impact of a 3 degree warming for the United States.

A full assessment of the impact of greenhouse warming must, of course, include regions outside the United States. To date, studies for other countries are fragmentary, and it is not possible to make any general conclusions at this time. A preliminary reading is that other advanced industrial countries will experience modest impacts similar to those of the United States, and some may even have net economic benefits; for example, Fankhauser (1993) extends his analysis and estimates losses from CO₂ doubling of 1.4 percent to OECD countries and 1.5 for the world. Another estimate, more qualitative in nature, is an intensive survey of experts on the economic impacts of climate change

(Nordhaus, 1993b). For a 3 degree C warming in 2090, the median response was an economic loss of 1.8 percent of world output. However, there is great uncertainty: the median estimate of the 10th percentile of outcomes is for no impact, while the median estimate of the 90th percentile of outcomes is for a 5.5 percent loss of world output.

All these studies indicate the great uncertainty about the impact of climate change. More recent analysis suggests that the studies reported in Table 1 may well overestimate the impact of climate change because they ignore many ways in which economies can adapt to changing climate. One kind of adaptation ignored in most studies is the buffering of shocks by trade. A study by Reilly and Hohmann (1993) begins with the results of agricultural production-function studies such as those used in Table 1; these studies estimate the impact of climate change on crop yields in individual regions. These yield estimates are then imbedded in a model of international trade. Reilly and Hohmann find that trade tends to reduce the economic impacts by a factor of from five to ten as reactions of supply and demand buffer production shocks. For example, the estimated impact of a substantial (30 percent) yield shock in temperate regions, buffered by the adaptive response in markets, produces a negligible impact on incomes: 0.06 percent of income for the U.S. and 0.08 percent loss for the world over a period of nearly a century. This careful study is a good lesson on how impact estimates often tend to exaggerate losses while ignoring gains and adaptations.⁵

Another approach to measuring impacts is a "Ricardian" analysis that estimates the rents to climate in particular climate zones and then uses these to estimate the impact of climate change on income. The Ricardian approach is useful because it allows all forms of adaptation, whereas the production-function approaches omit all but a few forms of adaptation to changing climate. A study by Mendelsohn, Nordhaus, and Shaw (1993a, b) developed such an approach by examining the impact of climate on U.S. agriculture. This study uses cross-sectional data on climate, farm-land prices, and other economic and geophysical data for almost 3000 counties in the United States.

Applying the model to a global-warming scenario found a range of impacts. The traditional analysis of global warming analyzes the impact upon the

⁵One might suspect that there is often an unconscious impulse to find costs and ignore benefits of climate change. A comparison of two sets of studies is instructive in this respect. Almost two decades ago, a series of studies was undertaken to investigate the impact of flights in the stratosphere on global cooling. Studies by d'Arge and others (summarized in National Research Council, 1979) found that global cooling of 1° C would impose costs in a number of areas. Of the nine areas of costs identified in the global cooling studies (agriculture, forest products, marine resources, health, locational preferences, fuel demand, housing, public expenditures, and aesthetics), only two were examined in the 1989 EPA study of global warming and *none* were calculated by the EPA to produce benefits. The largest estimated cost in the global cooling studies was the amenity effect of cooling, determined through regional wage differentials. This topic was completely ignored in the EPA studies. One is tempted to say that environmental impact studies can find the cloud behind every silver lining.

grains. Under this approach, the Ricardian model finds annual losses ranging from \$6 to \$8 billion annually (without CO₂ fertilization in 1988 prices at 1988 levels of farm income). This can be related to gross farm income in 1982 of \$175 billion. Strikingly different results emerge if we use a broader approach which includes all agricultural crops. For these, the net impact of warming is slightly positive; ranging from a loss of \$0.7 billion to a *gain* of \$2 billion per year. The differing results arise because the broader approach weights relatively more heavily the irrigated lands of the American West and South that thrive in a Mediterranean and subtropical climate, a climate that will become relatively more abundant with a warmer climate.

The one area where our information is particularly sparse is for developing countries. Small and poor countries, particularly ones with low population mobility in narrowly restricted climatic zone, may be severely affected. Much more work on the potential impact of climate change on developing countries needs to be done.

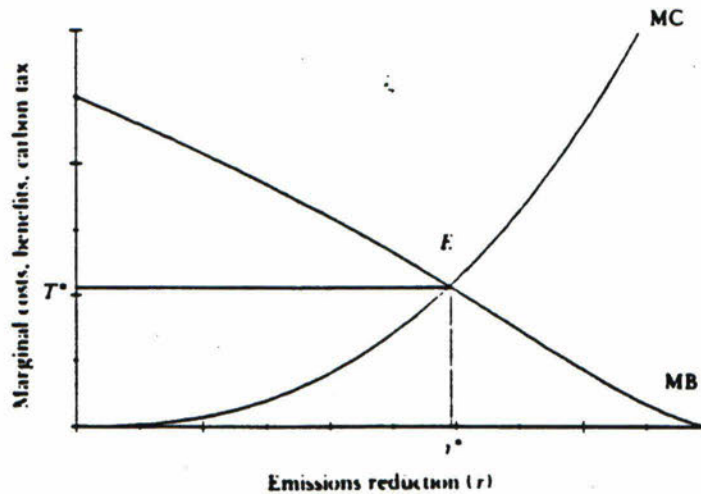
The Balancing Act in Climate Change Policies

The greenhouse effect is the granddaddy of public goods problems—emissions affect climate globally for centuries to come. Because of the climate externality, individuals will not produce the efficient quantity of greenhouse gases. An important goal of economic research is to examine policies that will find the right balance, on the margin, of costs of action to slow climate change and the benefits of reducing future damages from climate change.

The benefits of emissions reductions come when lower emissions reduce future climate-induced damages. To translate these into a marginal benefit function, it is necessary to follow the emissions through greenhouse-gas concentrations to economic impacts, and then take the present value of the impact of an emission of an additional unit. Graphically, we can depict the marginal damages averted per unit of emissions reduction as the downward-sloping marginal benefit (MB) curve in Figure 2.

The second relationship is the marginal cost of emissions reduction, which portrays the costs that the economy undertakes to reduce a unit of greenhouse-gas emissions (or the equivalent in other policies that would slow greenhouse warming). A wide variety of approaches are available to slow climate change. Most policy discussion has focussed on reducing CO₂ emissions by reducing the consumption of fossil fuels through energy conservation, alternative energy sources (some would even contemplate nuclear power), and other measures. Such policies could be implemented through carbon taxes of the kind James Poterba analyzes in this symposium, while some prefer regulations such as tradable emissions permits. Other approaches include reforestation to remove CO₂ from the atmosphere and putting even more stringent controls on CFCs.

Figure 2
Marginal Costs and Benefits of Greenhouse-Gas Emissions Controls



Note: Efficient policy comes at point E , where marginal cost of further emissions reduction (MC) equals marginal benefit of emissions reductions in slowing climate change (MB). T^* is the efficient carbon tax while r^* is the efficient reduction rate.

Another option, definitely not in the environmentally correct package, would be to offset greenhouse warming through climatic engineering, primarily through measures to change the albedo (reflectivity) of the earth. Such options include injecting particles that would increase the backscattering or reflecting of incoming sunlight or stimulate absorption of carbon. Two particularly interesting proposals include shooting smart mirrors into space with 16-inch naval rifles or seeding the oceans with iron to accelerate carbon sequestration.⁶ Whatever the approach, economists emphasize the importance of cost-effectiveness—structuring policies to get the maximal reduction in harmful climatic change for a given level of expenditure. Figure 2 shows schematically the marginal cost of cost-effective emissions reductions as MC .

The shape of the cost function for reducing CO_2 emissions has been thoroughly studied, and the effort discussed by John Weyant in this symposium represents the most careful comparative examination of the results of different models. In addition, policies should include other cost-effective measures, and a recent National Academy of Sciences Panel (1992) has compared the costs of a wide variety of measures, including rough estimates of the costs of climate engineering.

From an economic point of view, efficient policies are ones in which the marginal costs are balanced with the marginal benefits of emissions reductions. Figure 2 shows schematically how the efficient rate of emissions reduction and

⁶The issues of geoengineering are discussed in National Academy of Sciences (1992, Chapter 28).

the optimal carbon tax are determined. The pure market solution comes with emissions reductions at 0, where MB is far above the zero MC. Point E represents the efficient point at which marginal abatement costs equal marginal benefits from slowing climate change. The policy can be represented by the efficient fractional reduction in emissions, r^* on the horizontal axis, or by the optimal carbon tax, T^* on the vertical axis.

Empirical Modeling of Optimal Policies

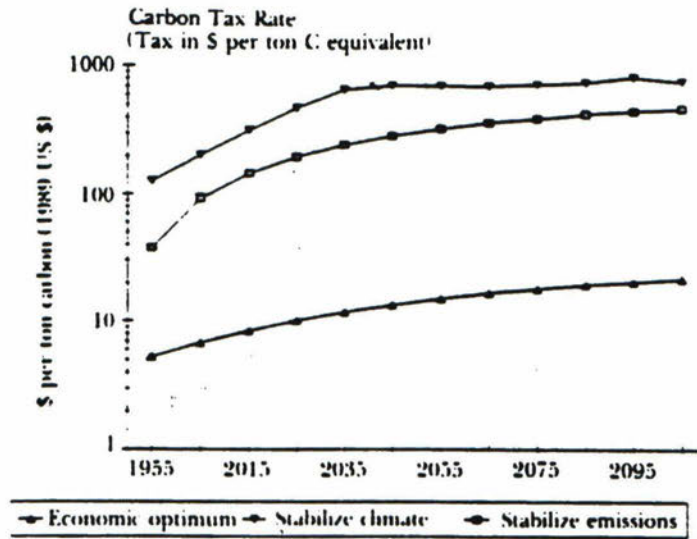
Sketching the optimal policy in Figure 2 demands little more than pencil, paper, and a rudimentary understanding of economics. To move from theory to useful empirical models requires understanding a wide variety of empirical economic and geophysical relationships. Work has progressed to the point where the economics and natural science can be integrated to estimate optimal control strategies. In one study, I developed a simple cost-benefit analysis for determining the optimal steady-state control of CO_2 and other greenhouse gases based on the comparative statics framework shown in Figure 2 (Nordhaus, 1991). This earlier study came to a middle-of-the-road conclusion that the threat of greenhouse warming was sufficient to justify low-cost steps to slow the pace of climate change.

A more complete elaboration has been made using an approach I call the "DICE model," shorthand for a Dynamic Integrated Model of Climate and the Economy.⁷ The DICE model is a global dynamic optimization model for estimating the optimal path of reductions of greenhouse-gas emissions. The basic approach is to calculate the optimal path for both capital accumulation and reductions of greenhouse-gas emissions in the framework of the Ramsey (1928) model of intertemporal choice. The resulting trajectory can be interpreted as the most efficient path for slowing climate change given inputs and technologies; an alternative interpretation is as a competitive market equilibrium in which externalities or spillover effects are corrected using the appropriate social prices for greenhouse-gas emissions.

The DICE model asks whether to consume goods and services, invest in productive capital, or slow climate change via reducing greenhouse-gas emissions. The optimal path chosen is one that maximizes an objective function that is the discounted sum of the utilities of per capita consumption. Consumption and investment are constrained by a conventional set of economic relationships (Cobb-Douglas production function, capital-balance equation, and so forth) and by a newly developed set of aggregate geophysical constraints (interrelating economic activity, greenhouse gas emissions and concentrations, climate change, costs of abatement, and impacts from climate change).

⁷The basic model and results are presented in Nordhaus (1992a, b), while complete documentation and analysis are forthcoming in Nordhaus (1993a).

Figure 3
Calculated Carbon Taxes for Three Policies



To give the flavor of the results from the DICE model, consider the economic optimum and compare it to two alternative policies that have been proposed by governments or by the environmental community. The three options are (1) economic optimization as described in the previous paragraph; (2) stabilizing greenhouse-gas emissions at 1990 levels, a target that was endorsed at the Rio Earth Summit by the United States and other governments; and (3) stabilizing climate so that the change in global average temperature is limited to no more than 0.2 degrees C per decade with an ultimate limitation of 1.5 degrees C (compare this with the projections in Figure 1).

Solving the DICE model for the three policies just described produces a time sequence of consumption, investment, greenhouse-gas emissions, and carbon taxes. The carbon taxes can be interpreted as the taxes on greenhouse-gas emissions (or the regulatory equivalent, say in auctionable emissions rights) that would lead to the emissions that would attain the policy objectives just described.

Figure 3 shows the resulting carbon taxes. For calibration purposes, in the United States, a carbon tax of \$100 per ton would raise coal prices by about \$70 per ton, or 300 percent; would increase oil prices by about \$8 per barrel; and would raise around \$200 billion of revenues (before taking account of emissions reductions). The economic optimum produces relatively modest carbon taxes, rising from around \$5 per ton carbon to around \$20 per ton by the end of the next century. The stabilization scenarios require much more stringent restraints. For emissions stabilization, the carbon tax would rise from around \$40 per ton of carbon currently to around \$500 per ton late in the next century;

climate stabilization involves current carbon taxes over \$100 per ton carbon today rising to nearly \$1000 per ton by the end of the next century.

The DICE model can also be used to inquire into the estimated net economic impact of alternative policies. For the global economy, the economic optimum has a net benefit over no controls for the global economy (in terms of the discounted present value measured in 1990 consumption units) of \$270 billion. On the other hand, stabilizing emissions or climate imposes major net economic costs. Stabilizing emissions leads to a net present-value loss of around \$7 trillion relative to the optimum, while attempting to stabilize climate would have a net present-value cost of around \$41 trillion. If these present value figures are converted into consumption annuities using an annuity rate of 4 percent per annum, these strategies represent, respectively, a gain of 0.05 percent and losses of 1.4 and 8.2 percent of today's annual gross world output. It would take a major misestimate of either the costs of emissions reductions or of climate-change damages to make the stabilization options economically advantageous.

Several other economic studies have also calculated efficient approaches to slowing global warming. The studies of Manne and Richels (1990, 1992), Peck and Teisberg (1992), and Kolstad (1993) find conclusions roughly similar to those reported here. Other studies—those of Kolstad (1993) as well as earlier studies by the present author (1979, 1991)—also determine the optimal emissions control rates and carbon taxes and show optimal policies in the general range of those determined here.

Two studies derive quite different results, one more optimistic, one more pessimistic. The studies by Jorgenson and Wilcoxon (1991, most strikingly) show a lower set of carbon taxes needed to stabilize greenhouse-gas emissions than those shown here; the reason for the lower carbon taxes seems to reside largely in the slow projected economic growth. By contrast, the study by Cline (1992) proposes much higher control rates. The more stringent controls in the Cline study are due to a number of features—primarily because the Cline result is not grounded in explicit intertemporal optimization and assumes a rate of time preference that is lower than would be consistent with observed real interest rates. Clearly, if we arbitrarily assume a near-zero discount rate (as Cline does), society will undertake massive investments in tangible, human, and environmental capital; who will do all this saving is an unanswered question.

Uncertainties and Anxieties

Most economic studies of the impacts and policies concerning climate change are based on scenarios like the smooth and gradual warming depicted in Figure 1. And, as indicated in the last section, the conclusion that emerges from most economic studies is to impose modest restraints, pack up our tools, and concentrate on more pressing problems. Given the high costs of controls

and the modest projected impacts of a 1 to 3 degree C warming over the next half century, how high should global warming be on an international agenda that includes exploding population in the South, nuclear proliferation in the Middle East, collapsing economies in eastern Europe, increasing cycles of poverty and drug use along with stagnating incomes in the West, and sporadic outbreaks of violence and civil war just about everywhere? Given the modest estimated impact of climate change along with these other urgent concerns, we might conclude that global warming should be demoted to a second-tier issue.

Yet, even for those who downplay the urgency of the most likely scenarios for climate change, a deeper anxiety remains about future uncertainties and surprises. Scientists raise the specter of shifting currents turning Europe into Alaska, of mid-continental drying transforming grain belts into deserts, of great rivers drying up as snow packs disappear, of severe storms wiping out whole populations of low-lying regions, of surging ice sheets raising ocean levels by 20 to 50 feet, of northward migration of old or new tropical pests and diseases decimating the temperate regions, of environmentally induced migration overrunning borders in search of livable land. Given the potential for catastrophic surprises, perhaps we should conclude that the major concern lies in the uncertainties and imponderable impacts of climate change rather than in the smooth changes foreseen by the global models.

At present, we do not have the scientific basis for making a firm judgment of the likelihood of one of these catastrophic outcomes. In the survey discussed above (Nordhaus, 1993b), experts were asked about the probability of a 25 percent sustained loss in global income from a 3-degree C warming in 2090 (scenario A) and a 6-degree warming in 2175 (scenario B). The median estimated probability of this catastrophic outcome was 0.5 percent for scenario A and 3 percent for scenario B. On the other hand, the assessment of the catastrophic scenarios varied greatly across respondents and particularly across disciplines. For scenario B, according to the most pessimistic quartile of respondents, the mean probability of this catastrophic outcome was 40 percent. The more pessimistic assessments generally came from natural scientists while the more sanguine views were held by mainstream economists.

Once the door is open to consider catastrophic changes, a whole new debate is engaged. If we do not know how human activities will affect the thin layer of life-supporting activities that gave birth to and nurture human civilization, and if we cannot reliably judge how potential geophysical changes will affect civilization or the world around us, can we use the plain vanilla cost-benefit analysis (or even the Häagen-Dazs variety in dynamic optimization models)? Should we be ultraconservative and tilt toward preserving the natural world at the expense of economic growth and development? Do we dare put human betterment before the preservation of natural systems and trust that human ingenuity will bail us out should Nature deal us a nasty hand?

Faced with this dilemma, we might be tempted to say that such questions are beyond the capability of rational analysis and turn the decisions over to

philosophers and politicians. Rather, I believe that natural and social sciences have a central role to play in analyzing potential future outcomes and delineating potential responses. Society often requires that decisions be made in the absence of complete information, whether the decisions be military strategy, oil drilling, or research and development. In each case, a reasoned decision process involves listing the events that may occur, estimating the consequences of the events, judging the probabilities that each of the events will occur, weighing the expected value of the consequences against the expected costs under different courses of action, and choosing the action that maximizes the expected value or utility of the outcome.

Reasoned decision-making under uncertainty is no different for climate-change policy than for other areas, although it may be more complex and require crossing traditional disciplinary boundaries more often. In thinking through the appropriate treatment of future surprises, to the natural scientists falls the crucial task of sorting through the apocalyptic scenarios and obtaining rough judgments as to the likelihood of different geophysical outcomes so as to distinguish between the likely, plausible, possible, and virtually impossible. To the social scientists falls the issue of assessing the probabilities, determining the values of different outcomes, and devising sensible strategies in the face of such massive uncertainties. To our leaders falls the burden of ultimately deciding how to balance future perils against present costs. For all, this is a fruitful use of our collective talents, full of intellectual challenges and practical payoffs.

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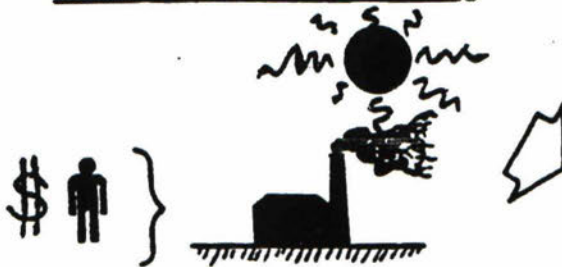
GLOBAL WARMING: WHAT WE KNOW & WHAT WE DON'T KNOW

DAN ALBRITTON - NAT'L OCEANIC & ATMOSPHERIC ADMINISTRATION (NOAA)

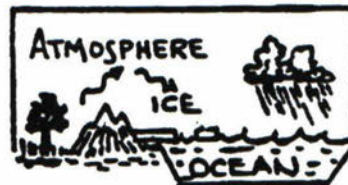
DEPUTIES COMMITTEE ON CLIMATE CHANGE
DOS, 19 NOVEMBER 1996

► CONTEXT: THE CLIMATE SYSTEM & HUMANKIND

• CLIMATE CHANGE FORCINGS



• PHYSICAL PROCESSES



• PHYSICAL RESPONSES



• BIOLOGICAL PROCESSES

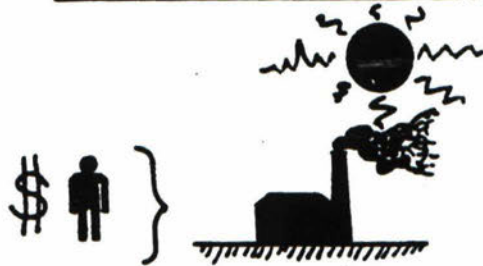
- CROP YIELD
- COASTAL HABITATION
- FOREST MIGRATION
- ...

• IMPACTS

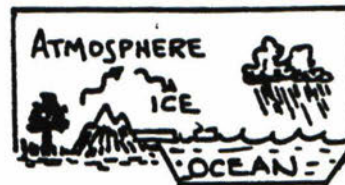
GLOBAL WARMING: WHAT WE KNOW & WHAT WE DON'T KNOW

► CONTEXT: THE CLIMATE SYSTEM & HUMANKIND

• CLIMATE CHANGE FORCINGS



• PHYSICAL PROCESSES



THREE MAJOR QUESTIONS:

★ • HOW WELL DO WE UNDERSTAND THE CLIMATE SYSTEM & OUR ROLE IN CHANGING IT?

• HOW WELL CAN WE CHARACTERIZE THE IMPACTS OF CLIMATE CHANGE?

• WHAT ARE OUR FUTURE OPTIONS?



• PHYSICAL RESPONSES



- CROP YIELD
- COASTAL HABITATION
- FOREST MIGRATION
- ⋮



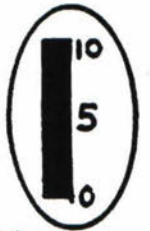
• BIOLOGICAL PROCESSES

• IMPACTS

A SCIENTIFIC STATUS REPORT



THERE IS A NATURAL GREENHOUSE EFFECT.
IT KEEPS THE EARTH WARMER THAN
IT WOULD BE OTHERWISE.



"CONFIDENCE INDEX"

POINTS...

● IN TERMS OF BASIC PHYSICS:

② IT WARMS UP AND...

③ IT EMITS INFRARED LIGHT.



① IF AN OBJECT IS BATHED IN VISIBLE LIGHT...

● IN TERMS OF OUR PLANET EARTH:

<u>ATMOSPHERE</u>	<u>ABUNDANCE</u>
NITROGEN	78%
OXYGEN	20
⋮	
★ WATER VAPOR	2%
CARBON DIOXIDE	0.03
⋮	
↑ GREENHOUSE GASES	



● KEY ASPECTS

- > WATER VAPOR & CARBON DIOXIDE HAVE BEEN PART OF OUR ATMOSPHERE FOR MILLIONS OF YEARS.
- > THEIR PRESENCE YIELDS AN AVERAGE SURFACE TEMPERATURE OF ~60° F.
- > WITHOUT THEM, THE AVERAGE WOULD BE ~5° F.

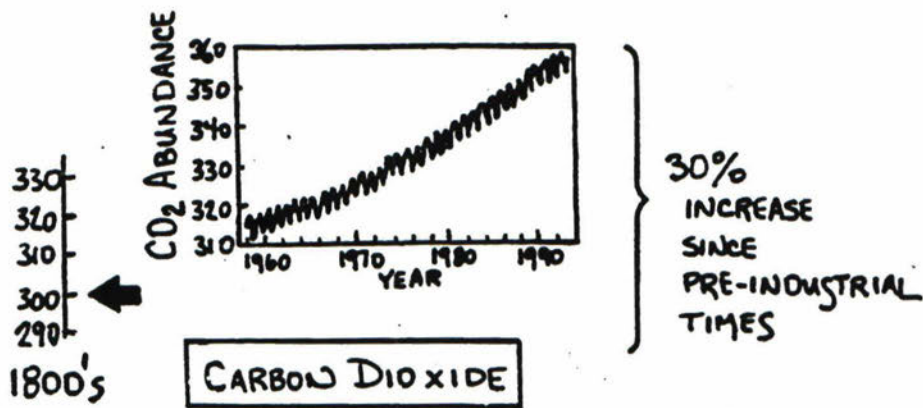
So ... WHAT'S THE PROBLEM?

➡ GREENHOUSE GASES ARE INCREASING IN THE ATMOSPHERE BECAUSE OF HUMAN ACTIVITIES, AND THEY ARE INCREASINGLY TRAPPING MORE HEAT :



POINTS...

- IMPECCABLE SCIENTIFIC MEASUREMENTS



- OTHER GASES ARE INCREASING TOO

METHANE,
FOR EXAMPLE
 $\times 2+$

- THE SOURCES ARE HUMAN-CAUSED

$\text{CO}_2 \sim \text{ALL}$
METHANE $\sim \text{MOST}$

Q: BUT, WHAT ARE THE POTENTIAL CONSEQUENCES?

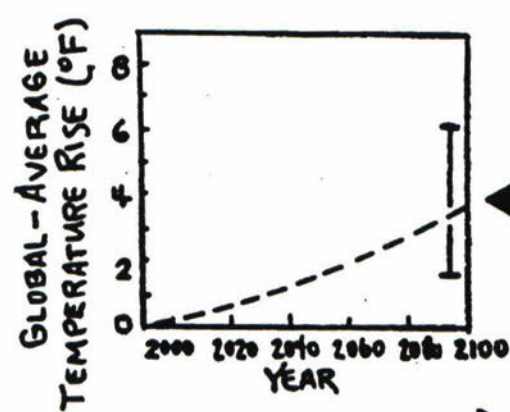
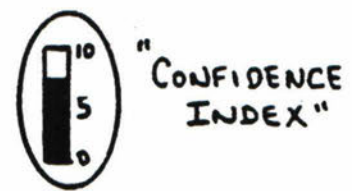
➡ A CONTINUED FUTURE GROWTH IN GREENHOUSE GASES IS PREDICTED TO LEAD TO VERY SIGNIFICANT CLIMATE CHANGES.

POINTS...

- CO₂ ABUNDANCE LIKELY COULD DOUBLE AROUND 2100

INDEED ... TO STABILIZE AT DOUBLED → CUTS IN EMISSIONS
TO RETURN TO TODAY'S → DEEP CUTS

- PREDICTED CLIMATE RESPONSES.



"BEST ESTIMATE": $3\frac{1}{2}$ °F INCREASE IN TEMPERATURES AVERAGED OVER THE GLOBE.

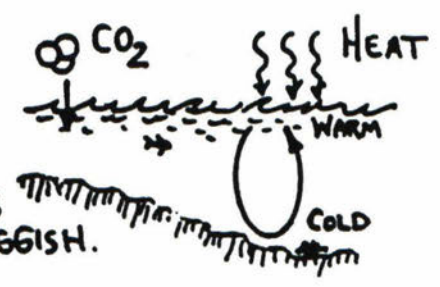
> IF SO, THIS WOULD EXCEED THE NATURAL CHANGES OVER THE PAST 10,000 YEARS.

> CORRESPONDING SEA LEVEL RISE : ~20 INCHES.

- A GREENHOUSE WARMING COULD ONLY BE REVERSED VERY SLOWLY.

REASON:

THE OCEANS ARE SLUGGISH.



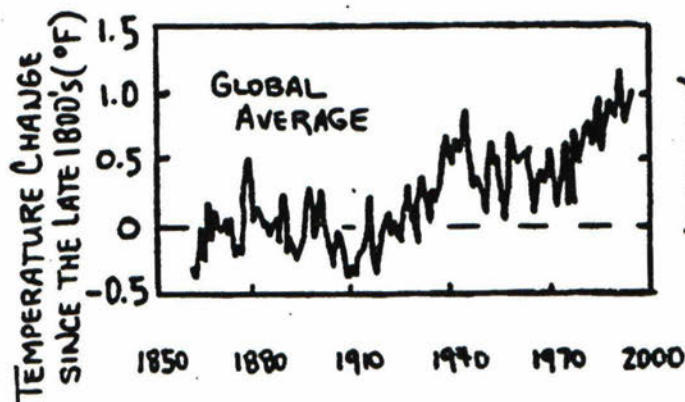
Q: HAVE WE SEEN ANY WARMING YET?



GLOBAL TEMPERATURES HAVE WARMED OVER THE PAST CENTURY & THE BALANCE OF EVIDENCE SUGGESTS A DISCERNABLE HUMAN INFLUENCE.

POINTS...

GLOBAL TEMPERATURE MEASUREMENTS



THE EARTH (ON THE AVERAGE) HAS WARMED 0.5-1.0 °F OVER THE PAST 100+ YEARS.

> SLOW, NATURAL SWINGS IN TEMPERATURE SINCE THE LAST ICE AGE ARE NOT DISSIMILAR IN SIZE.

THE OBSERVED WARMING IS UNLIKELY TO BE ENTIRELY NATURAL.

⇒ 1995 IPCC
"human activities likely influencing..."
only possible in 1995

REASONS:

COMPARISONS OF TEMPERATURE-CHANGE PATTERNS:

PREDICTIONS ↔ OBSERVATIONS

REGIONAL
SEASONAL
VERTICAL

PATTERN OF CHANGES
• PREDICTIONS
• OBSERVATIONS
TEND TO CORRESPOND

☑ CORRESPONDENCES INCREASE WITH TIME

☑ PROBABILITY IS LOW THAT A "NATURAL-ONLY" EARTH WOULD HAVE SUCH CORRESPONDENCES

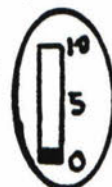


Q: BEYOND "GLOBAL AVERAGES"?

➡ IT IS A COMPLEX PLANET & WE HAVE IMPERFECT KNOWLEDGE,
SO, PREDICTION OF FURTHER DETAILS SUFFERS.

POINTS...

● WHAT WILL HAPPEN IN PARTICULAR PLACES?



● REGIONAL CHANGES CANNOT YET BE PREDICTED RELIABLY.

- INDICATIONS ARE:
 - LAND WARMS MORE THAN OCEANS } WINTER.
 - MAX N. HI-LATITUDE WARMING }
- TEMPERATURES BETTER PREDICTED THAN RAINFALL.

● HOW ABOUT "EXTREME EVENTS"?

> A WARMER WORLD → A MORE-VIGOROUS HYDROLOGICAL CYCLE *more evap, convection, etc.*

PERHAPS
MORE
VARIATION

FLOODS/DROUGHTS:
MORE OR LESS SEVERE,
FROM REGION-TO-REGION.

> HURRICANES: MORE/LESS FREQUENT? INSUFFICIENT KNOWLEDGE

● SURPRISES?

- > ABRUPT CLIMATE SHIFTS?
- > CURRENTLY UNKNOWN GEOPHYSICAL PROCESSES ACTIVATED?

POSSIBLE. HERE'S WHY:

- ENTERING A NEW REGIME OF CLIMATE PERTURBATION.
- CLIMATE IS A NONLINEAR SYSTEM:

CONCLUDING COMMENTS

● BOTTOM LINES THE VAST-MAJORITY SCIENTIFIC VIEWPOINT:

- THE ISSUE IS A REAL ONE.
- SOME HUMAN-INDUCED CLIMATE CHANGE APPEARS INEVITABLE.
- DISCERNABLE "FIRST SIGNS" ARE SUGGESTED NOW.
- EXACTLY WHERE (REGIONS)
WHEN (RATE OF CHANGE) IS HARD TO PREDICT.
HOW MUCH (MAGNITUDE)
- HUMAN-INDUCED CLIMATE CHANGE WOULD BE SLOW TO REVERSE.

● BASIS OF THIS INFORMATION

INTERGOVERNMENT PANEL ON CLIMATE CHANGE



OFF THE PRESS: APR/MAY '96

ASSESSMENTS:

- PREPARED BY EXPERT COMMUNITIES.
- INTERNATIONALLY BASED.
- "ONE-STOP SHOPPING" FOR THE ISSUE.



THE LAST BOTTOM LINE:

KEY INPUT
TO POLICY
DECISIONS



Greenhouse Gases

- * Emissions resulting from human activities are substantially increasing the atmospheric concentrations of greenhouse gases, especially carbon dioxide, methane and nitrous oxide. The primary anthropogenic sources are:

Carbon dioxide: combustion of fossil fuels, land-use changes and cement production.

Methane: coal mining, natural gas leakages, landfills, cattle, rice

Nitrous oxide: adipic acid (nylon) and nitric acid production

Recent Findings and Key Uncertainties:

The processes controlling the fluxes of carbon dioxide between the atmosphere and the oceanic and terrestrial ecosystems (i.e., the magnitude of the terrestrial and oceanic sinks) are not quantitatively understood. However, evidence is mounting that there is a significant terrestrial sink of carbon dioxide. This means that the net emissions from land-use change, and the relationship between emissions and atmospheric concentrations, are poorly quantified. *eg Brazil is net SINK, still.* *↑ convention points to conc. not em.*

The magnitude of the individual sources of methane and nitrous oxide on a global scale are quite uncertain. *well known: fossil (coal mining)*
not: rice, land

The rate of increase of atmospheric methane has slowed by about a factor of two over the last few years. $1\%/yr \rightarrow 1/2\%/yr$.
Sources? or sinks?

Greenhouse Gases (continued)

* Other important greenhouse gases include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), fully fluorinated chemicals (e.g., CF_4), and upper tropospheric and lower stratospheric ozone. *not controlled by MP → growth. ← $\text{O}_3 \downarrow$ to radiative forcing of net* *fully offset?*

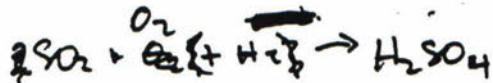
CFCs and HCFCs: The net radiative effect of CFCs (and most likely HCFCs) is less than previously believed because the chlorine-induced loss of ozone in the lower stratosphere offsets the direct radiative forcing of the CFCs (and most likely HCFCs). The role of HCFCs in climate change is limited because their production and consumption are controlled under the Copenhagen amendments to the Montreal Protocol.

HFCs: These gases, which are partial substitutes for the CFCs, are quite strong greenhouse gases. HFCs are not controlled under the Montreal Protocol because they are not ozone depleting substances, hence there is potential for significant growth in production and consumption, i.e., emissions.

Fully Fluorinated Chemicals: While the current emission rates of these gases is relatively low, they have very long lifetimes.

Tropospheric ozone: Ozone in the upper troposphere is a powerful greenhouse gas, hence any increase in upper tropospheric ozone would amplify the enhanced greenhouse affect. However, the atmospheric trend data for both ozone and it's precursors is sparse and often of limited quality.

Atmospheric Aerosols



- * The cooling effect of aerosols resulting from sulfur emissions or from biomass burning may have directly and/or indirectly offset a significant part of the enhanced greenhouse warming in the northern hemisphere during the past several decades.
- * The impact of aerosols in the future will depend upon the magnitude and the regional distribution of emissions for sulfur gases, e.g., sulfur dioxide, and the extent of biomass burning.
- * The atmospheric lifetimes for aerosols and their precursors is very short (days to weeks) in contrast to the very long lifetimes (decades to centuries) of the key greenhouse gases. Therefore, their effect on global warming rapidly adjusts to increases or decreases in emissions.

↳ Nothing others

China's extra high S coal

GCM Model Results

- * The sensitivity of global mean surface temperature to doubling of carbon dioxide is unlikely to lie outside the range 1.5 to 4.5 degrees centigrade.
- * Time-dependent simulations, with coupled ocean-atmosphere models, in which neither aerosol or ozone changes have been included, suggest a warming rate of about 0.3 degrees centigrade per decade for the central IPCC trace gas scenarios, e.g., IPCC 1990 scenario A. *↳ Puts HGA in aerosols,*
- * Coupled ocean-atmosphere models are now capable of reproducing some features of atmospheric variability on intra-decadal time scales, i.e., a variability of a few tenths of a degree centigrade.
- * The large scale geographic patterns of warming predicted from transient coupled ocean-atmosphere models are similar to the patterns predicted from equilibrium models, except that the transient simulations show a reduced warming over the North Atlantic and the southern oceans near Antarctica.

+500.

Climate Observations

- * the global mean surface air temperature has increased by 0.3 to 0.6 degrees centigrade over the past 100 years.
- * the observed warming over parts of the northern hemisphere mid-latitude continents has been found to be largely characterized by increases in minimum (night-time) rather than maximum (day-time) temperatures.
*Produced by model? not say aerosols reflected daytime (~ more clouds). Problem? **
- * global mean surface temperatures were anomalously high (highest on record) in the late 1980s and 1990 and 1991.
- * the volcanic eruption of Mt. Pinatubo in 1991 resulted in a transitory warming of the stratosphere and a cooling of the troposphere. *but reflected back up to 1992 cold*
- * radiosonde data indicate that the lower troposphere has warmed over recent decades. Since meaningful trends cannot be assessed over periods as short as a decade, the widely reported disagreements between decadal trends of air temperatures from satellites and surface data cannot be confirmed because the trends are statistically indistinguishable.

* No: Ag. likes higher min (diurnal + annual)

Yes: oceans don't care. + ecosystems might not

Impacts of Climate Change

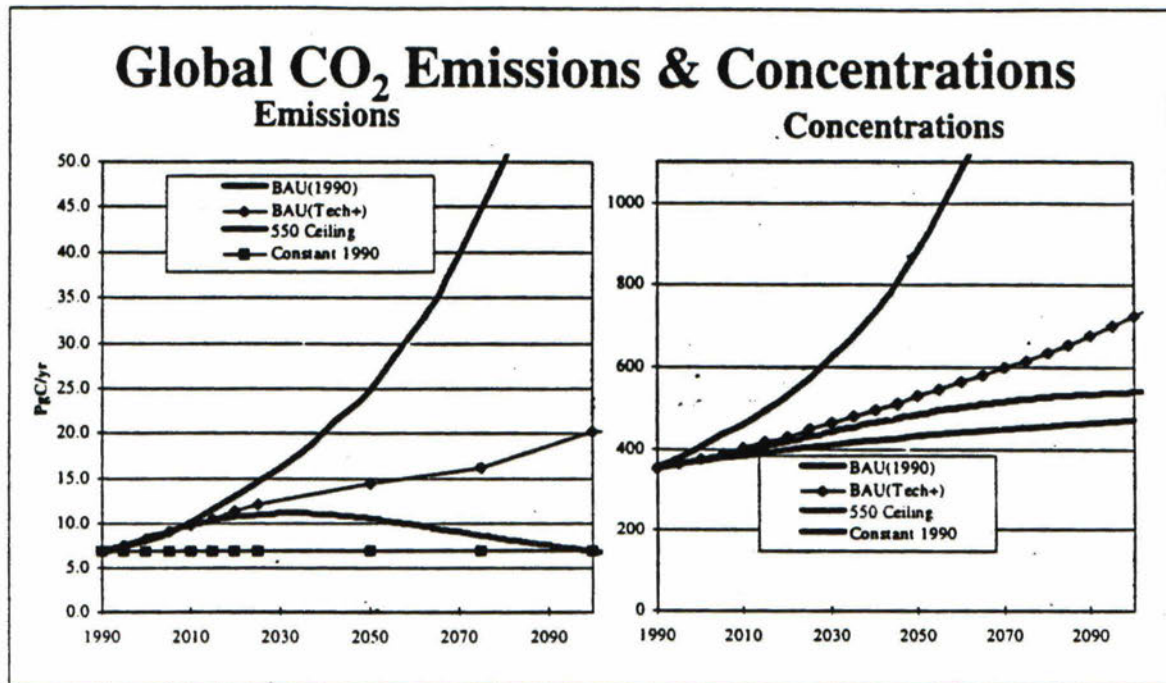
- * Climate change will have consequences for agriculture and forestry, natural terrestrial ecosystems, hydrology and water resources, human settlements, human health, air quality, oceans and coastal zones (sea level rise), seasonal snow cover, ice and permafrost, and the energy, transport, and industrial sectors.
- * The most significant potential impacts of climate change are likely to include:
 - a sea level increase of up to one meter by 2100
 - changes in regional patterns of precipitation and soil moisture, leading to changes in agricultural productivity
 - shifts in the productivity and boundaries of natural terrestrial ecosystems.
- * *Winners/Losers?*

Conclusions

- * the size of the observed global warming is broadly consistent with predictions from climate models, but is also of the same size as natural climate variability. Thus the observed increase could be largely due to this natural variability; alternatively this variability and other human factors could have offset a still larger human-induced greenhouse warming.
- * the consistency between observations of global mean temperature trends over the past century and model simulations of the warming due to greenhouse gases over the same period is improved if allowance is made for the increasing evidence of a relative cooling effect due to anthropogenic aerosols (from sulfur emissions and biomass burning) and stratospheric ozone depletion.
- * the estimated warming of about 0.3 degrees centigrade per decade, based on the central 1990 and 1992 IPCC emission scenarios, should be reduced somewhat, especially in the northern hemisphere, by an amount dependent upon the future magnitude and regional distribution of sulfur and biomass burning emissions.
- * there are many uncertainties in our predictions particularly with regard to the timing, magnitude and regional patterns of climate change. This is due to an incomplete understanding of:
 - the role of clouds
 - the role of the oceans
 - sources and sinks of greenhouse gases
 - land-surface hydrological processes
 - cryospheric processes
 - ecological processes

- * the long atmospheric lifetimes of the greenhouse gases means that if climate change occurs with adverse environmental consequences the damage cannot be reversed for many decades or centuries even with major changes in greenhouse gas emissions.

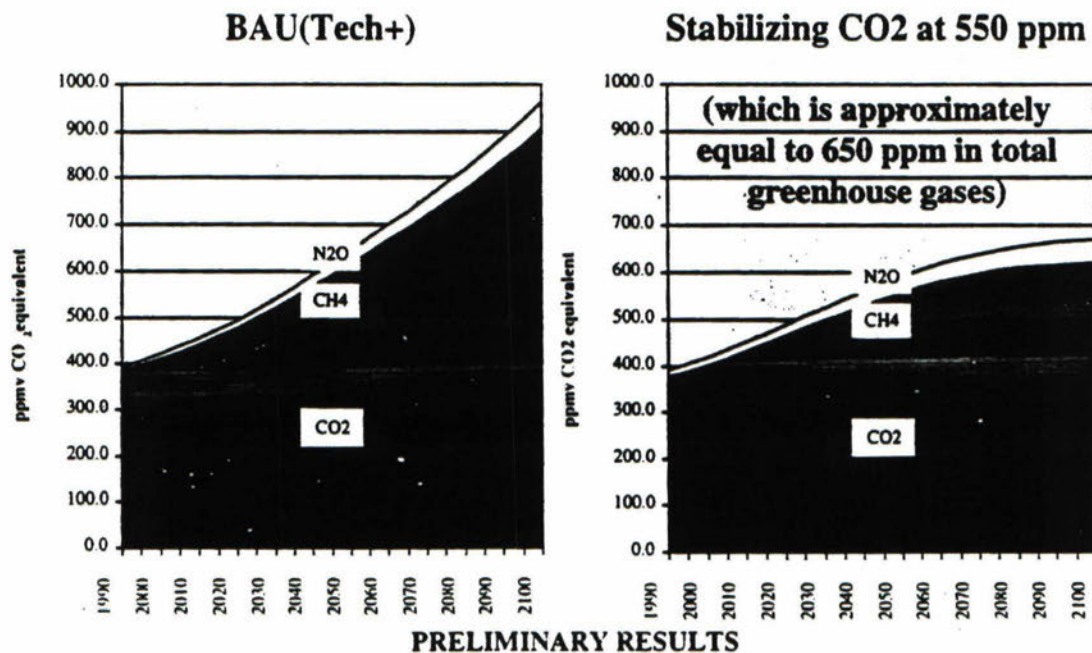
KEY POINT #1:



- If we continue on a Business-As-Usual (BAU) path (top 2 lines in above figures), concentrations will double over the next few decades, never achieving stabilization.
- Stabilizing emissions will not stabilize concentrations.

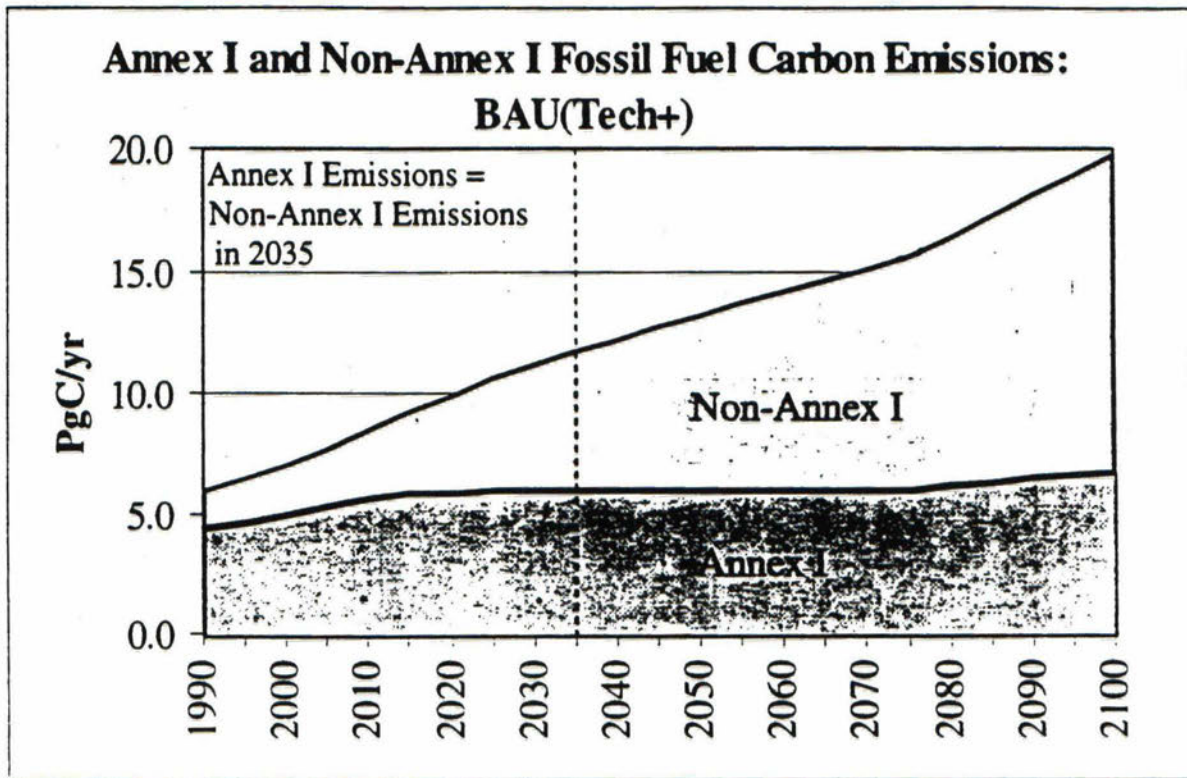
KEY POINT #2:

Non-CO₂ greenhouse gases make the “effective” atmospheric concentration higher.



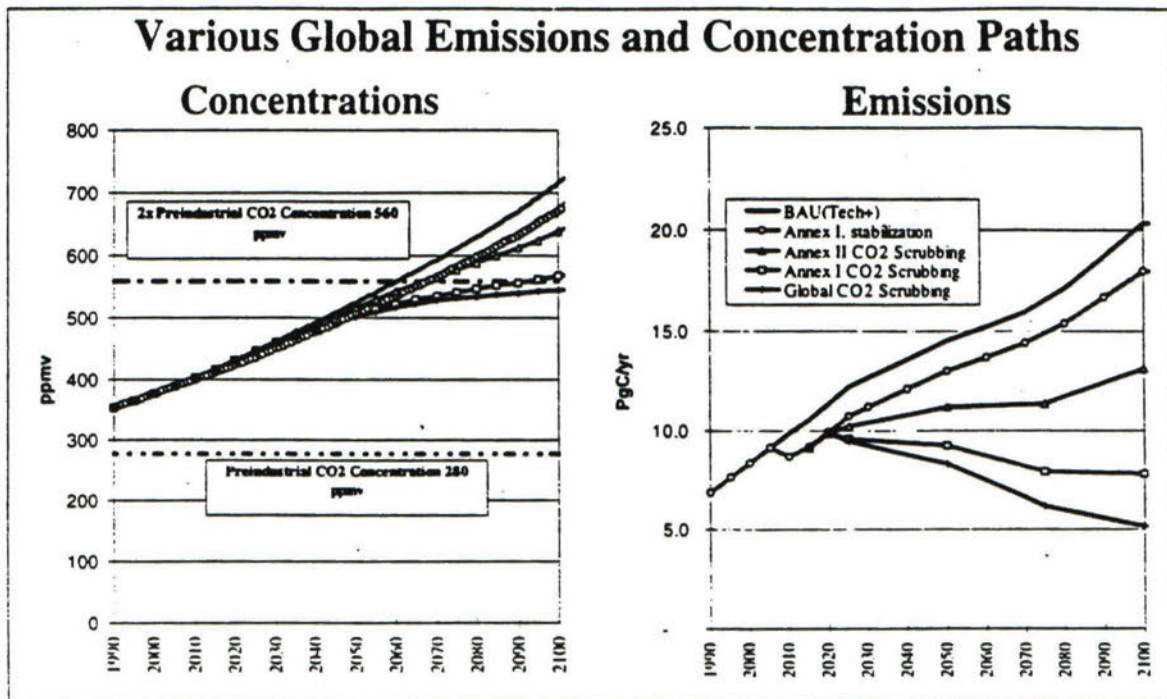
- Other greenhouse gases, principally methane and nitrous oxides, make the “effective” atmospheric concentrations about 20% higher than carbon dioxide alone.
- Most stabilization scenarios have been unable to incorporate changes in all the gases simultaneously, but it is important to consider that a “550 CO₂ stabilization” scenario represents an “effective atmospheric concentration” of about 650.

KEY POINT #3:



- A Business-As-Usual path implies that over time the majority of emissions will shift from developed to developing nations.

KEY POINT #4:



- Actions by Annex I alone are insufficient to achieve stabilization
- In order to cap emissions at just under a doubling of pre-industrial CO₂ levels, actions by Annex I countries need to be coupled with actions by non-Annex I countries in the next few decades.

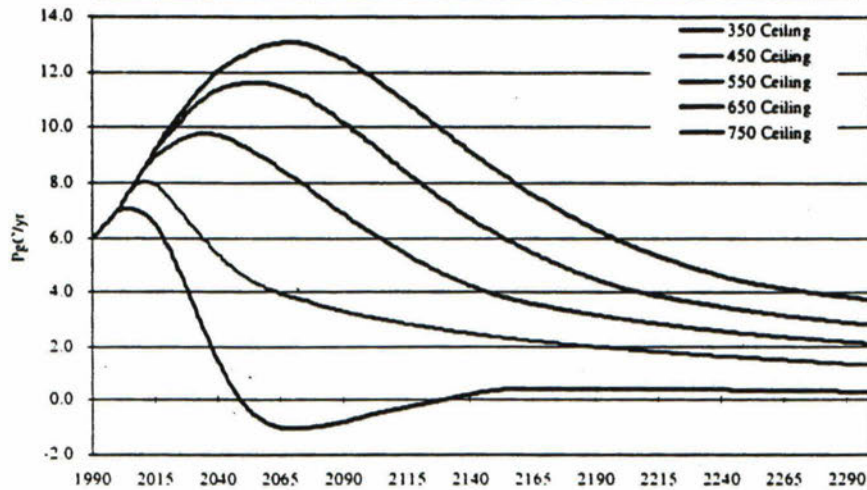
KEY POINT #5:

Energy emission pathways and stabilization concentrations

Steady-State Concentration →	350 ppmv	450 ppmv	550 ppmv	750 ppmv
Deflection Date BAU (Tech+) ^a	2007	2013	2018	2023
Maximum Emission Date	2011	2033	2049	2062
Maximum Emission ^b	8.0	9.7	11.4	12.5

^a The deflection date is the year in which emissions in the emissions stabilization trajectory first fall below BAU emissions by more than 0.1 PgC/yr.

^b Maximum PgC/yr fossil fuel carbon emissions. If other greenhouse gases are included, emissions would be effectively 20% higher; thus, reductions would have to occur sooner than the deflection date noted to achieve a given concentration.



- To meet atmospheric concentrations of 450-750 ppmv CO₂ requires a significant reduction in annual emissions during the next century.

- For example, to meet a target of 550 ppmv CO₂, the table shows that global CO₂ emissions due to fossil fuel burning must begin to deflect from the business-as-usual curve by 2013. In that scenario, energy-related emissions would peak at 9.7 PgC/yr in 2033 and drop rapidly thereafter. (Because of the other greenhouse gases, the effective concentration would be about 650 ppmv.)

The most important is to amend the act to prohibit secondary boycotts and thus bring restraints on rail labor in line with those imposed on labor organizations in other industries that are subject to the National Labor Relations Act. It should be noted that he offers no opinion on whether such an amendment is possible. Sharp declines in railroad employment in recent years have reduced the political power of rail unions, but they are still a force to be reckoned with on Capitol Hill.

Other suggestions Wilner offers for improvement in the act include lengthening the term of National Mediation Board members beyond the present three years and setting minimum standards for board members to ensure their expertise in matters they are called on to consider.

Finally, he suggests that the board itself should act to reduce the number of bargaining units, which have multiplied in recent years as a result of rail mergers. Giant rail systems such as Burlington Northern, CSX, and Norfolk Southern now have to deal with multiple general chairmen in each craft because of their continued representation of these crafts on the constituent carriers.

More or less as an aside, Wilner suggests that if the president and Congress would exercise more restraint in injecting themselves into the collective bargaining process each time an "insoluble" labor dispute developed, the parties in their own self-interest might find that the "insoluble dispute" was solvable after all. Maybe so, but despite the fact that the railroads now handle less than 40 percent of intercity freight traffic, there are still many giant shoppers who would suffer irreparable loss from a national rail strike of any duration. It is a safe bet that they would be on the doorsteps of the White House and Congress long before the insoluble dispute became solvable, and the president and Congress would intervene as usual.

One final subject addressed by Wilner has nothing to do with the Railway Labor Act—or at least no one suspected that it did for over fifty years. The subject is income protection for rail workers who are dismissed or demoted as the result of a merger, sale, abandonment, or exercise of track-age rights involving a line of railroad. Beginning in 1933, a pattern evolved through legislation, court and administrative decisions, and agreement of the parties whereby displaced employees were assured continuing income for a prescribed period. Changing economic conditions and a consequent decline in union power have brought changes to that pattern in the past few years, however. And in certain types of transactions (such as the sale of a railroad or a part of a railroad to a

noncarrier), the courts have held that statutory protective conditions now found in the Interstate Commerce Act do not apply. As a result, beginning in 1986 the unions took the position that any proposed sale that would affect employees constituted a change in working conditions that would require notice and bargaining under the Railway Labor Act, which, of course, would mean that the transaction would never take place. This was a novel approach, and in a way it was at least indirectly successful. While the principal contention of the unions was rejected by the courts, it was rejected in the context of the right to strike. A federal circuit court of appeals has now held that such disputes are "minor" under the act and, therefore, must be submitted to an adjustment board for arbitration. Presumably, a carrier faced with that prospect would prefer the certainty of negotiated settlement over the uncertainty of an arbitration award.

Wilner has performed a real service in writing this book. Management, labor, rail analysts, and students can develop an understanding of railroad labor problems in these 118 pages that they could never find elsewhere without many months of study. At the same time, they can take pleasure in reading a well-written and enjoyable book.

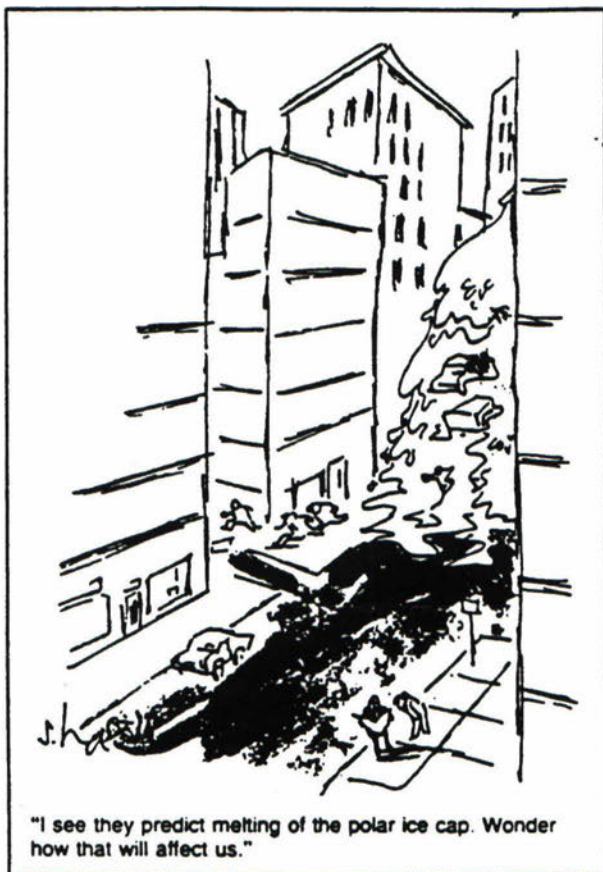
Assessing the Cost of Greenhouse Abatement

Buying Greenhouse Insurance: The Economic Costs of CO₂ Emission Limits
by Alan S. Manne and Richard G. Richels

Reviewed by Ray Squitieri

Some say the world will end in fire. Some say in ice. Fifteen years ago the vote was ice. These days it is fire. Thousands of natural scientists are now sifting the data in an attempt to decide. The United States alone will spend \$1.4 billion in 1993 on global climate research. Yet, thus far, on a topic that cries out for clear economic thinking, only a few economists have published serious research. Among those, Alan Manne of Stanford University and Richard Richels of the Electric Power Research Institute are two of the most prominent.

Ray Squitieri is a senior staff economist at the Council of Economic Advisers.



Buying Greenhouse Insurance, which collects articles originally published elsewhere, concludes that world economies would pay dearly for deep cuts in carbon dioxide emissions, but leaves open the possibility that such actions may make sense as insurance.

The book is timely. In early 1992 the European Community challenged the United States to commit to stabilize carbon dioxide emissions at 1990 levels. The United States has so far declined to do so, but the issue will dominate the environmental debate throughout the 1990s.

In the policy debate to date proponents of immediate action ("Ready, fire, aim!") argue that the stakes are so high that immediate action is justified, even in the face of considerable scientific uncertainty about the likelihood, timing, and effects of global warming. They point to risks of irreversible damage and claim that low-cost alternatives to fossil fuels are already on the shelf. The opposition ("Ready, aim, aim!") urges caution. First, they argue that global warming itself may not arrive; second, that humans could readily adapt to warming; third, that the costs of abatement are likely to be large; and fourth, that the

cost of waiting a decade or so before committing to costly actions is small. Economists have so far concerned themselves with the third and fourth issues. Their research has generally vindicated the wait-and-see approach.

Recent research has concluded that uniform national emissions targets do not make economic sense because of the wide divergence in control costs across countries. More efficient schemes such as tradeable permits or a uniform tax could cut costs by half. In addition, research has shown that treaties should not focus on fuel-burning carbon dioxide emissions alone. Tree planting and methane control will be cheaper in some places, at least up to a point. Economists have also found that no agreement will work without cooperation by the less developed countries, which are expected to be the main emitters within a few decades.

In the brave new world of computer modeling, researchers represent the United States or the world economy in a set of equations. Manne and Richels, along with most of their brethren, built their model, Global 2100, to answer the question, "What would be the costs of limits on carbon dioxide emissions from fuel burning?" Global 2100 is based on Manne's well-respected work from the "energy crisis" days of the mid-1970s. Like a dozen other research groups worldwide, Manne and Richels consider only the costs, not the benefits, of slowing warming; and they consider only the costs of restricting carbon dioxide emissions from fossil fuel burning while they omit the costs of reducing methane from livestock and landfills or expanding forests and other carbon sinks.

Even after those simplifications, greenhouse abatement presents the modeler with a series of nasty complications: a very long time horizon (Manne and Richels run theirs out to the year 2100; William Cline runs his to 2300); large uncertainties about population and economic growth, energy demand, and technical innovation; an irreducibly global problem (trade flows are crucial); the possibility of irreversible damages or severe limits on economic growth. Noting the evident difficulty of predicting GNP growth or interest rates even one or two years in advance, skeptics have challenged the whole concept of hundred-year models.

Computer models addressing global warming fall into two categories. Optimal planning models such as Brookhaven National Laboratory's MARKAL focus on specific technologies and generally

conclude that many low-cost alternatives could reduce carbon dioxide emissions. Most economists believe that the optimal planning approach understates the costs of new technologies and overstates their impacts. Econometric models, such as that of Dale Jorgenson and Peter Wilcoxon, which is built around statistical relationships found in historical data, have generally concluded that policies to limit carbon dioxide emissions involve significant costs. Manne and Richels' Global 2100 lies closer to the optimal planning camp, although its conclusion—that carbon dioxide restrictions would involve significant costs—puts it closer to the econometric camp.

Effective computer modeling is a balancing act in which sectoral detail, consistency with economic theory, and transparency must each appear in the right proportions. While none of today's models fully meets all those requirements, Global 2100 comes close. It expands the optimal planning design to link five regional models, representing the entire world. It contains the most satisfying treatment of the energy sector and the clearest simple treatment of feedback to economywide output. And it is transparent, at least in comparison with large, "black box" econometric models.

Of course, Global 2100 does have its limitations. Assessing impacts on different industries would require a model with more sectoral detail, such as that developed by Jorgenson and Wilcoxon. Identifying short-run costs of adjustment would require a short-run macro model, such as that of Data Resources Incorporated. Single-country detail requires a single-country model, such as the handful of U.S.-only models. Comparing long-run effects of different carbon tax regimes may require a computable general equilibrium model such as Lawrence Goulder's. Further, despite its name, Global 2100 is global only in a limited sense: its five world regions trade nothing except oil and carbon emissions permits.

Those limitations aside, Manne and Richels offer valuable insights on the costs of limiting carbon dioxide emissions. Reducing U.S. carbon dioxide emissions from fuel use by 20 percent from 1990 levels would cost about 2.5 percent of U.S. GNP by 2030. (For comparison, the average recession reduces long-run U.S. GNP by about 1 percent). The 20 percent cut would cost 1 to 2 percent of GNP in the rest of the Organization for Economic Cooperation and Development, which has a less carbon-intensive economy, and 3 percent in the more carbon-intensive economies of

the former Eastern bloc and Soviet Union. China, with the most coal and the most ambitious economic growth targets, would face a crushing cost of 5 percent of GNP by 2100. Hardly anyone thinks China will sign on to policies that wipe out its future GNP growth. And if China and other developing countries do not sign a worldwide agreement, economic growth will drive up their carbon dioxide emissions enough to swamp emissions cuts made by the rich countries. (Manne and Richels expect worldwide GNP to grow by a factor of five over the next century.) Jae Edmonds and Richard Barnes have calculated that without cooperation by the less-developed countries, the world could not achieve a 20 percent cut in carbon dioxide emissions by 2020, even if the OECD eliminated carbon dioxide emissions entirely.

Manne and Richels make another important contribution when they frame the question of greenhouse abatement as one of decisionmaking under uncertainty. With the large gaps in current scientific knowledge, many have urged early action to slash carbon dioxide emissions, as a kind of insurance against possible catastrophe. But as the authors demonstrate, an aggressive research program could provide its own greenhouse insurance by answering the question, "Is a catastrophe possible?" in time to take action. With an aggressive research program in place, waiting a decade or so before making costly commitments becomes an attractive alternative.

Some researchers have criticized Manne and Richels as too pessimistic on the costs of reductions. Princeton's Robert Williams, for example, asserts that Manne and Richels' work significantly overstates the costs of new, less carbon-intensive technologies. When Stanford's Energy Modeling Forum compared the results of a dozen related models, all run on a consistent set of assumptions, Global 2100 appeared at the high end of the range.

On the other hand, Manne and Richels neglect certain factors that would make control costs even higher. For example, Global 2100 implicitly assumes the most efficient control policies. Further, Harvard's William Hogan and Dale Jorgenson believe that Global 2100 omits an important indirect cost. They find evidence from the past several decades that productivity growth is associated with increasing energy intensity, and thus that restrictions on carbon dioxide emissions, by reducing energy use, would depress total factor productivity (the measure of output divided by all inputs taken together), and thus economic growth.

Over the next decade three questions will dominate the policy debates: How far should we go in curbing greenhouse emissions? What will be counted? And how are the costs to be shared?

Manne and Richels and their colleagues have already taken important steps toward answering those questions. Policymakers should take heed.

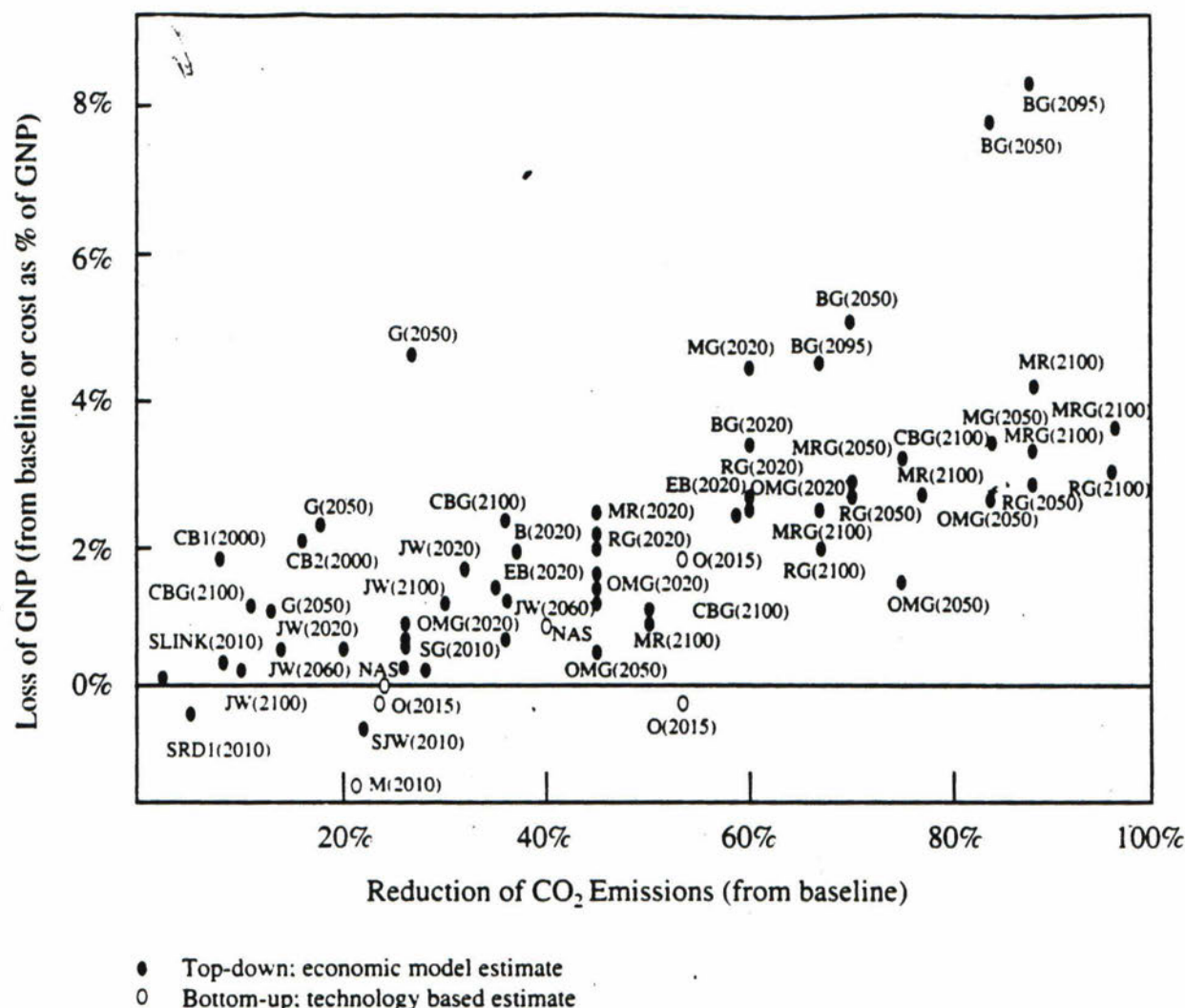
SUMMARY

- Estimates of the cost of greenhouse gas emission reduction are sensitive to assumptions about appropriate model structure, demographic and economic growth, the cost and availability of both demand-side and supply-side energy options, the desired level and timing of abatement, and the choice of policy instruments. Different assumptions have led to a wide range of emission reduction cost estimates.
- Despite significant differences in views, there is agreement that some energy efficiency improvements (perhaps 10-30% of current consumption, depending on baseline assumptions and the implementation time frame) can be realized at negative to slightly positive costs. The existence of such a no-regrets potential depends on the existence of substantial market or institutional imperfections that prevent cost-effective emission reduction measures from being taken. The key question is whether such imperfections can be removed cost effectively by policy measures.
- Energy-related emissions can be reduced through both demand-side (energy efficiency) and supply-side (alternative sources of supply) options. In the short term, demand-side options are cheapest in most countries.
- Estimates of the costs of stabilizing CO₂ emissions vary widely as a result of differences in both the baseline scenarios used (e.g., how much energy efficiency or what rate of economic growth is contained in the baseline scenario) and the calculated costs of various policy measures.
- There has been much more analysis to date of emission reduction potentials and costs for industrialized countries than for other parts of the world. Moreover, many existing models are not well suited to the study of economies in transition or developing country economies. Much more work is needed to develop and apply models outside of developed countries.
- The overall cost of abatement programmes will ultimately be determined by the rate of capital replacement, the discount rate, and the effect of research and development. Appropriate long-run signals to encourage research and development will reduce long-run costs. The implementation of any no-regrets potential will increase the time available to learn about climate risks and to bring new technologies to the marketplace.
- Infrastructure decisions are critical because they can enhance or restrict the number and types of future options, and different infrastructure decisions can lead to very different cost outcomes. This issue is of particular importance to developing countries, where major infrastructure decisions will be made in the near term.
- If the climate issue is formulated in terms of stabilizing atmospheric concentrations, the choice of emission time path is critical in determining the overall price tag. It is important to identify those paths that minimize the costs of achieving a particular concentration target.
- The overall impact of a carbon tax will depend not only on the size of the tax, but also on the uses to which the revenues are put. If carbon tax revenues are used to reduce more distortionary taxes, overall emission reduction costs will be reduced. Inefficient tax recycling could, however, increase costs.
- There is need for both detailed (bottom-up) analysis of technological options and also more aggregate (top-down) analysis of economic effects. Whereas, historically, these two approaches have been associated with very different cost estimates, this need not always be the case. Indeed, widely differing methods can produce quite similar results when calibrated to the same set of input assumptions.
- Given differences in marginal emission reduction costs among countries, international cooperation can significantly reduce the global price tag for emission reduction. Economic efficiency would be enhanced by carrying out emission reduction where it is cheapest to do so.
- Estimates of the costs of stabilizing CO₂ emissions at 1990 levels in *OECD countries* vary widely. Many bottom-up studies suggest that the costs of achieving this target over the next few decades may be negligible. Given rising baseline emissions over the longer term, however, many top-down studies suggest that the annual costs of stabilizing emissions may ultimately exceed 1-2% of GDP.
- The costs of stabilizing emissions for *economies in transition* may be small relative to OECD countries. The potential for cost-effective reductions in energy use is apt to be considerable, but the realizable potential will depend on what economic and technological develop-

ment path is chosen. A critical issue is the future of structural changes in these countries that may drastically change the level of baseline emissions and the emission reduction costs.

- Analyses suggest that there may be substantial low-cost emission reduction opportunities for developing coun-

tries. However, these are likely to be insufficient to offset rapidly increasing emission baselines associated with, for example, increased economic growth. In the absence of a highly favourable allocation of carbon emission rights, the likely magnitude of emission reduction will be particularly costly for developing countries.



Note: to avoid crowding, labels are not attached to all points. For key to studies used, see Table 9.1.

Source: Grubb *et al.* (1993).

Figure 9.1: U.S. Studies: Cost of CO₂ abatement relative to baseline projection.

9.1 Introduction

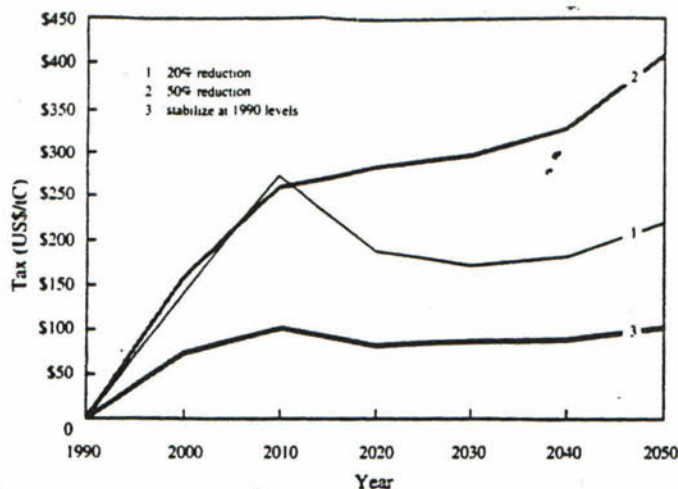
A variety of options can be adopted in response to the prospect of increasing concentrations of greenhouse gases in the earth's atmosphere. These include (1) options that eliminate or reduce greenhouse gas emissions; (2) options that offset emissions, for example, through the enhancement of sinks; and (3) options that help human and ecological systems adjust or adapt to new climate conditions and events. The first and second types of interventions take effect prior to climate change and are intended to slow its pace. As such, they are referred to as "mitigation" measures. The third category of intervention takes place after warming occurs and falls under the classification of "adaptation." This chapter reviews existing studies of the economic costs of mitigating greenhouse gas emissions.

A caveat is in order. Sensible greenhouse policy should involve careful consideration of the costs of mitigation and adaptation options together with what these options may buy

in terms of reduced environmental impacts. This chapter focusses exclusively on mitigation costs. The benefits from adopting such options are discussed in Chapter 6.

9.2 Review of Existing Studies of the Costs of Reducing CO₂ Emissions

In recent years, there have been numerous studies of the costs of reducing CO₂ emissions. Unfortunately, estimates have spanned such a wide range that they have been of limited value to policy making. Figure 9.1 and Table 9.1, which summarize recent projections of the costs of reducing U.S. CO₂ emissions, are illustrative of the current lack of consensus about the costs of emission reduction. Whereas some studies place losses at several percent of GDP, others question whether there will be any losses at all. An essential first step in narrowing the range of disagreement is to determine why estimates differ so widely.



Source: EMF (1993).

Figure 9.4: U.S. carbon taxes – average of all models.

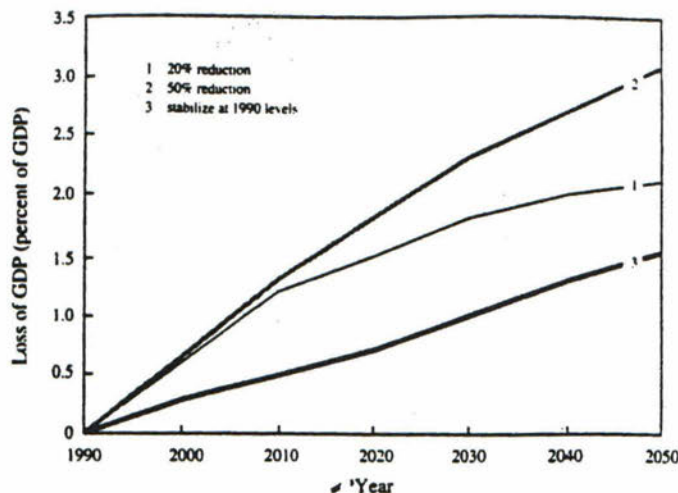
Table 9.4 compares model results for the stabilization and 20% reduction scenarios. Estimates range from \$20 to \$150 per tonne for the carbon taxes required to hold emissions at 1990 levels in 2010. Estimates of the carbon taxes required to reduce emissions by 20% below 1990 levels in 2010 range from \$50 to \$330 per tonne.

Two parameters are particularly important in explaining the differences in tax projections: the price elasticity of energy demand and the speed with which the capital stock adjusts to higher energy prices. Neither was controlled in the EMF experiments but rather they were left to the choice of the modellers. Not surprisingly, those models using lower price elasticities required higher taxes to achieve the same emission goal. Those models which assumed greater malleability of capital required lower taxes.

The wide spread in the numerical results should not, however, obscure the fact that the models were in agreement on a number of important points. First, despite the inclusion of improved technologies and improved energy efficiencies in the reference case, all the models projected that intervention would be required to achieve the emission targets.

Second, the size of the required tax increases with the stringency of the carbon limit. The tax paths shown in Figure 9.4 represent averages of the model results: Note that the size of the required tax doubles as the limit is tightened to 20% below 1990 levels and nearly doubles again for a 50% reduction. This suggests that the economic efforts to be devoted are non-linear with respect to the level of controls in any given year. That is, incremental reductions are apt to cost more as the absolute level of allowable emissions is reduced.

Figure 9.4 also suggests that the size of the carbon tax is apt to vary over time, even for the same target. Recall that the purpose of the tax is to raise the price of carbon-intensive fuels to the point where consumers will turn to price-induced conservation and less carbon-intensive supply alternatives. Hence, the size of the tax is determined by the cost differential



Source: EMF (1993).

Figure 9.5: U.S. GDP loss projections – average of all models.

between the marginal sources of supply with and without a carbon constraint. This cost differential is apt to change over time.

9.2.1.1.4 GDP losses

Table 9.4 shows a marked variation in GDP losses across models. Stabilizing emissions at their 1990 levels is estimated to reduce GDP by 0.2-0.7% in the year 2010 – roughly a \$20 billion to \$70 billion loss for that year. Estimates of the costs of reducing emissions by 20% below 1990 levels in the year 2010 range from 0.9 to 1.7% of GDP.

In making these calculations, the modellers assumed a lump sum redistribution of tax revenues. That is, tax revenues are used to replace other tax payments by individuals and corporations without affecting marginal tax rates or total tax revenues. The GDP losses calculated in this manner measure the cost of the distortions to the economy caused by the imposition of the carbon tax. There are no credits or penalties for lump sum recycling of tax revenues. The assumption of lump sum recycling avoids confusing the economic impacts of carbon taxes with costs or benefits attributable to potential uses of the revenues.

Figure 9.5 shows the average GDP losses across models. Holding emissions at 1990 levels results in a 0.3% loss in 2000. This rises to 1.5% by the middle of the century. That GDP losses increase over time should come as no surprise. Increasing amounts of carbon must be removed from the energy system in order to hold emissions to a particular target. GDP losses also increase with the stringency of the target. With a 20% reduction, losses exceed 2% of GDP in 2050. With a 50% reduction, losses exceed 3% of GDP.

It is interesting that GDP losses for a given year are influenced by expectations about limits in future years. All three emission reduction scenarios require that emissions be stabilized at 1990 levels by the year 2000. Yet losses are higher in 2000 for the scenarios that eventually require further reductions. The reason is that energy investments are typically long